

# MONTHLY WEATHER REVIEW

APRIL 1940

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## AN INSTRUMENT FOR THE SPECTROSCOPIC DETERMINATION OF PRECIPITABLE ATMOSPHERIC WATER VAPOR, AND ITS CALIBRATION

By IRVING F. HAND

[Weather Bureau, Washington, D. C., January 1940]

The regular daily determination of the amount of precipitable water in the atmosphere is of importance in meteorology for both practical and theoretical purposes. Surface determinations have been made by means of the

The Weather Bureau is now greatly indebted to the Smithsonian Institution which, through the courtesy of Charles G. Abbot and L. B. Aldrich, designed and fabricated for the Weather Bureau an improved type of water-

### OPTICAL TRAIN, WATER-VAPOR SPECTROMETER

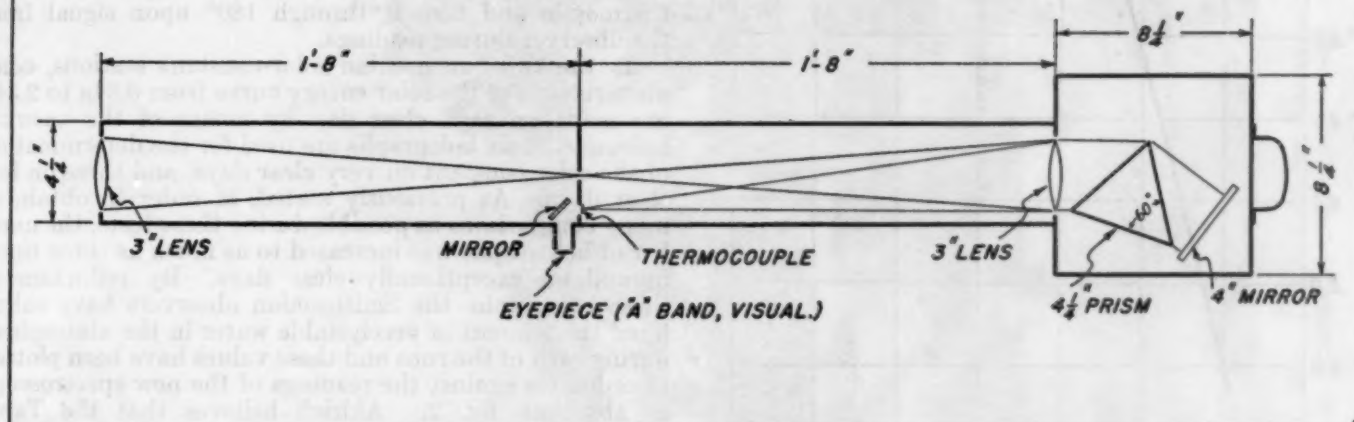


FIGURE 1.—Optical train of the water-vapor spectroscope.

psychrometer ever since the earliest days of meteorology: while the vertical distribution of water vapor has been determined to limited heights by kite, balloon, and airplane flights and, more recently, by means of the radiosonde. Some years ago, the Weather Bureau initiated optical determinations of precipitable water by pyrheliometric measurements of solar radiation through red and yellow filters which cut off long-wave radiation at approximately  $0.61 \mu$  and  $0.51 \mu$ , respectively.<sup>1</sup> However, this method is subject to considerable uncertainty, especially because the filters do not cut off sharply, and because of various assumptions, for example, the adoption of the value  $1.3 \mu$  for the average size of dust particles in the free atmosphere; our own atmospheric dust observations,<sup>2</sup> as well as observations by others, show the impracticability of using a constant factor for all environments.

<sup>1</sup> Kimball, Herbert H., and Hand, Irving F. The use of glass color screens in the study of atmospheric depletion of solar radiation. *Mo. Wea. Rev.*, March 1933, 61: 80-83.  
<sup>2</sup> Hand, Irving F. The character and magnitude of the dense dust-cloud which passed over Washington, D. C., May 11, 1934. *Mo. Wea. Rev.*, 62: 156-157, May 1934.

vapor spectroscope, of design similar to the one used by the Smithsonian Astrophysical Observatory about 8 years ago. We are further indebted to officials of the same Institution in permitting the calibration of the instrument at its two solar constant stations at Burro Mountain, N. Mex., and Table Mountain, Calif. At the first-named station Alfred F. Moore and Alfred D. Froiland more than doubled the usual total number of bolometric runs in order to obtain as many comparisons as possible; they also took turns in keeping the instrument pointed on the sun. Similar cooperation was furnished at Table Mountain by Fred A. Greeley and Stanley Warner.

The water-vapor instrument consists essentially of a spectroscope containing a collimator lens and a  $60^\circ$ -prism in a Littrow mounting, a lens to focus the solar rays on a slit  $\frac{1}{2}$  millimeter in width, and a thermocouple having two rectangular surfaces as nearly identical as it is practical to make them. Figure 1 shows the optical train, and figures 3 and 4 an exterior view of the instrument. The thermocouple,

designed and made by Leland B. Clark of the Smithsonian Institution, is of a new and highly efficient design. It is so arranged that by moving it into three different fixed positions, measurements may be made in different parts of the spectral band: The two sections of the solar energy spectrum observed are (A), a  $0.003\mu$  width centered around  $0.9560\mu$ , where the energy curve is not appreciably affected by water-vapor absorption; and (B), a  $0.003\mu$  width in the

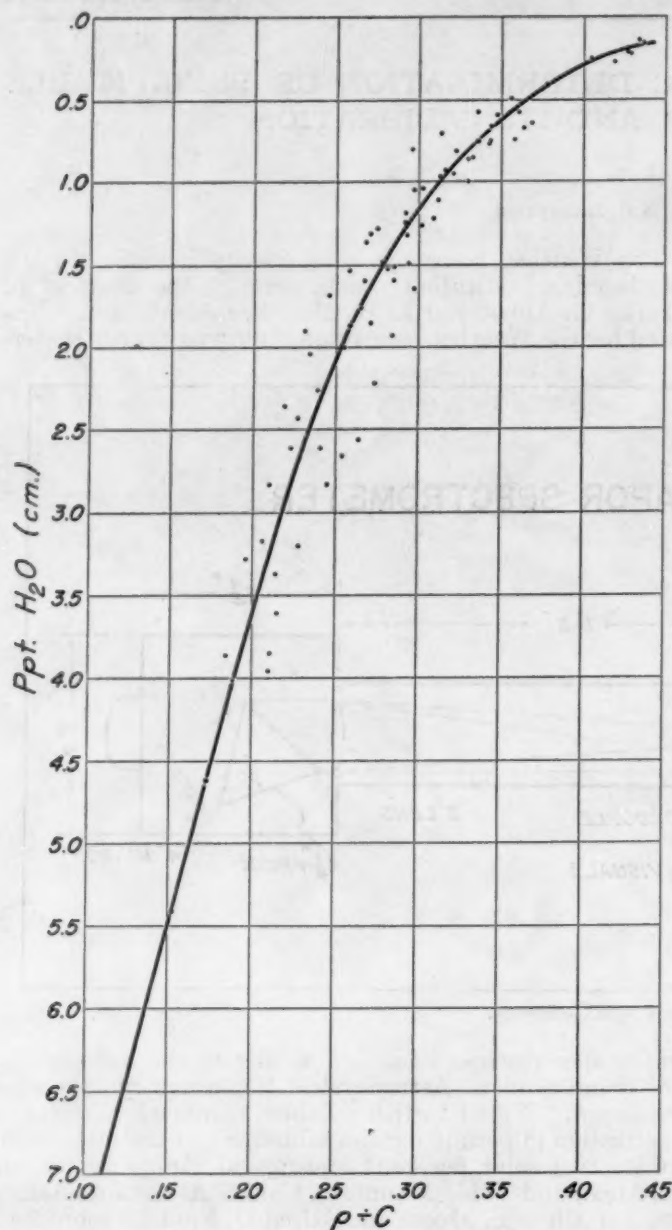


FIGURE 2.—Amounts of precipitable water corresponding to different ratios obtained by readings with the spectroscope.

center of the rho water-vapor absorption band at wavelength  $0.935\mu$ . The base line (C) is obtained by completely shading one strip. A high-sensitivity galvanometer is used for all measurements. In position 1, one strip on A and the other on B, we measure the differential between rho and the crest, or the diminution in energy owing to water-vapor absorption; in position 2, one strip on B and the other completely shaded, we obtain the height of rho above the base line; in position 3, one strip on A and the other completely shaded, we determine the energy at the crest, which should equal the sum of the energies obtained

in the first two positions.<sup>3</sup> This value also may be used for a rough determination of the total normal-incidence radiation.

To eliminate errors arising from inequalities in strip characteristics, the strips are reversed after making the initial reading in each position. Although any two of the positions would suffice for a reading, in actual practice all three positions are read and, as an added check, immediately reread in reverse order to minimize arithmetical errors.

The instrument is kept directed to the sun, manually, by means of a sight at the outer end of the tube through which a pencil of rays passes on to a target at the lower end. A circular opening near the outer end, through which the observer may see when the solar rays are concentrated centrally on the slit, enables him to make an appropriate spot on the target. A small prism projects the portion of the spectral band containing the A line at  $0.760\mu$  to a field which may be viewed by means of an eye-piece containing a cross hair, in order to obtain an approximate setting of the strips on the rho band. The final setting is effected by reading the instrument in position 2 and adjusting the mirror until a minimum reading is obtained. If the instrument is mounted rigidly in a fixed position neither of these adjustments is necessary except at infrequent intervals as checks. Owing to the great length of the tube and the extreme sensitivity of the thermocouple, it is necessary for one observer to continually make both altitude and azimuth adjustments, and at the same time change the position of the thermopile and turn it through  $180^\circ$  upon signal from the observer during readings.

At the two Smithsonian solar-constant stations, complete records of the solar energy curve from  $0.34\mu$  to  $2.34\mu$  are made on each clear day by means of the vacuum bolometer<sup>4</sup>; six bolographs are used for the determination of the solar constant on very clear days, and three on less clear days. As previously stated, in order to obtain as many comparisons as possible during these tests, the number of bolographs was increased to as much as three times normal on exceptionally clear days. By reduction of these bolographs the Smithsonian observers have calculated the amount of precipitable water in the atmosphere during each of the runs and these values have been plotted as ordinates against the readings of the new spectroscope as abscissas, fig. 2. Aldrich believes that the Table Mountain results give more accurate values of precipitable water in the atmosphere than the Burro Mountain readings; hence the Table Mountain calibrations have been used exclusively in preparing table 1, which gives the amounts of precipitable water corresponding to different readings of the new instrument.

All values obtained at Table Mountain (with the exception of those obtained on the morning of October 20 when the instrument obviously was out of adjustment) have been utilized for the calibration. The probable error of a single observation, calculated from the line of best of

all the readings by the formula  $0.6745 \sqrt{\frac{\sum v^2}{n-1}}$ , is  $\pm 0.19$  cm.

The individual half-day runs were also plotted, and the probable error of a single observation calculated from the lines of best fit; smooth curves were drawn, rather than lines zig-zagging from point to point. In general the curves of the individual half-day runs are very similar to

<sup>3</sup> Moore, A. F. Scouting for a site for a solar radiation station. Smithsonian Misc. Coll. Vol. 89, No. 4. Washington, 1933.

<sup>4</sup> Abbot, C. G., Fowle, F. E., and Aldrich, L. B. The Vacuum Bolometer. Annals of the Astrophysical Observatory of the Smithsonian Institution, Volume 4, Chapter 2, pp. 45-64. Washington, 1922.

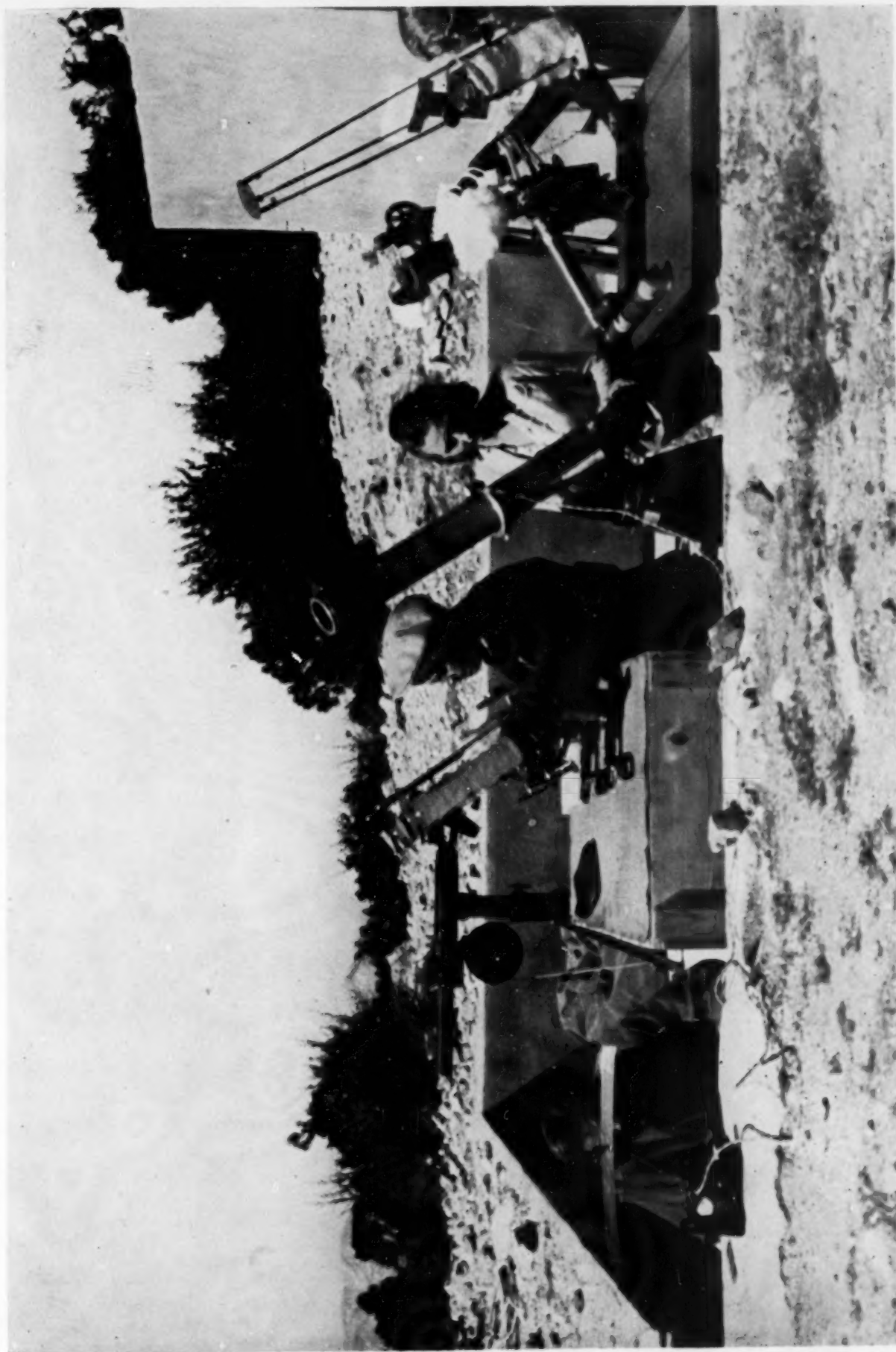


FIGURE 3.—Solar apparatus at Burro Mountain, N. Mex. Left to right, water-vapor galvanometer, coelostat, twin Smithsonian silver-disk pyrheliometers, water-vapor spectroscopic, Ångström pyrheliometer, theodolite, and pyranometer.



FIGURE 4.—Water-vapor spectroscope at Table Mountain, Calif. Radiation fog rising up slopes of the Blue Mountains.

the curve of all the observations, falling symmetrically on both sides of the latter; the instrument was adjusted on rho immediately preceding each run, but since it was impossible to exactly duplicate the settings with the temporary set-up of the instrument, each run was made with the strips set on a slightly different portion of the rho band, which explains why the individual days vary even though they closely parallel one another. It has been calculated that one half of the probable error of  $\pm 0.19$  cm. is due directly to these improper adjustments on rho; to eliminate this portion of the error, we shall replace the cross hair so that it bisects the double A line when the best possible setting on rho is made, and the settings may then be effected with great accuracy and with assurance that all are alike. The probable error of future readings should be thus reduced from  $\pm 0.19$  cm. to about  $\pm 0.10$  cm. This reduction is highly important because we shall be concerned chiefly with changes in the amounts of atmospheric water.

Table 2 gives the probable errors of single observations from the individual lines of half-day runs.

TABLE 1.—Amounts of precipitable water in centimeters corresponding to different ratios of  $\rho/C$  obtained with the water-vapor spectroscope

$\rho/C$	cm.	$\rho/C$	cm.	$\rho/C$	cm.	$\rho/C$	cm.	$\rho/C$	cm.	$\rho/C$	cm.	$\rho/C$	cm.
0.110	7.03	0.160	5.13	0.210	3.28	0.260	1.84	0.310	1.02	0.360	0.54	0.410	0.24
0.111	6.99	0.161	5.09	0.211	3.25	0.261	1.82	0.311	1.01	0.361	.53	0.411	.23
0.112	6.96	0.162	5.05	0.212	3.21	0.262	1.80	0.312	1.00	0.362	.52	0.412	.23
0.113	6.92	0.163	5.01	0.213	3.18	0.263	1.78	0.313	.99	0.363	.52	0.413	.23
0.114	6.88	0.164	4.97	0.214	3.15	0.264	1.76	0.314	.98	0.364	.51	0.414	.22
0.115	6.85	0.165	4.93	0.215	3.11	0.265	1.74	0.315	.97	0.365	.50	0.415	.22
0.116	6.81	0.166	4.89	0.216	3.08	0.266	1.72	0.316	.96	0.366	.50	0.416	.22
0.117	6.77	0.167	4.85	0.217	3.04	0.267	1.70	0.317	.95	0.367	.49	0.417	.21
0.118	6.74	0.168	4.80	0.218	3.00	0.268	1.68	0.318	.94	0.368	.48	0.418	.21
0.119	6.70	0.169	4.76	0.219	2.96	0.269	1.66	0.319	.92	0.369	.48	0.419	.21
0.120	6.67	0.170	4.72	0.220	2.93	0.270	1.64	0.320	.91	0.370	.47	0.420	.20
0.121	6.63	0.171	4.69	0.221	2.90	0.271	1.62	0.321	.90	0.371	.47	0.421	.20
0.122	6.59	0.172	4.65	0.222	2.87	0.272	1.60	0.322	.89	0.372	.46	0.422	.20
0.123	6.55	0.173	4.62	0.223	2.84	0.273	1.58	0.323	.88	0.373	.46	0.423	.19
0.124	6.51	0.174	4.58	0.224	2.81	0.274	1.56	0.324	.87	0.374	.45	0.424	.19
0.125	6.48	0.175	4.54	0.225	2.78	0.275	1.55	0.325	.86	0.375	.44	0.425	.19
0.126	6.44	0.176	4.51	0.226	2.74	0.276	1.53	0.326	.85	0.376	.44	0.426	.19
0.127	6.40	0.177	4.47	0.227	2.71	0.277	1.52	0.327	.84	0.377	.43	0.427	.18
0.128	6.37	0.178	4.43	0.228	2.68	0.278	1.50	0.328	.83	0.378	.42	0.428	.18
0.129	6.34	0.179	4.40	0.229	2.65	0.279	1.49	0.329	.82	0.379	.42	0.429	.18
0.130	6.30	0.180	4.36	0.230	2.62	0.280	1.47	0.330	.81	0.380	.41	0.430	.18
0.131	6.26	0.181	4.32	0.231	2.59	0.281	1.45	0.331	.80	0.381	.40	0.431	.18
0.132	6.22	0.182	4.28	0.232	2.56	0.282	1.44	0.332	.79	0.382	.40	0.432	.17
0.133	6.18	0.183	4.25	0.233	2.53	0.283	1.42	0.333	.78	0.383	.39	0.433	.17
0.134	6.14	0.184	4.21	0.234	2.50	0.284	1.40	0.334	.77	0.384	.38	0.434	.17
0.135	6.11	0.185	4.18	0.235	2.47	0.285	1.38	0.335	.76	0.385	.38	0.435	.17
0.136	6.07	0.186	4.14	0.236	2.45	0.286	1.36	0.336	.75	0.386	.37	0.436	.17
0.137	6.04	0.187	4.11	0.237	2.43	0.287	1.34	0.337	.74	0.387	.36	0.437	.16
0.138	6.00	0.188	4.07	0.238	2.41	0.288	1.32	0.338	.73	0.388	.36	0.438	.16
0.139	5.97	0.189	4.04	0.239	2.38	0.289	1.31	0.339	.72	0.389	.35	0.439	.16
0.140	5.93	0.190	4.00	0.240	2.36	0.290	1.29	0.340	.71	0.390	.34	0.440	.16
0.141	5.89	0.191	3.96	0.241	2.33	0.291	1.28	0.341	.70	0.391	.34	0.441	.16
0.142	5.85	0.192	3.93	0.242	2.30	0.292	1.27	0.342	.69	0.392	.33	0.442	.16
0.143	5.81	0.193	3.90	0.243	2.27	0.293	1.26	0.343	.68	0.393	.33	0.443	.16
0.144	5.77	0.194	3.87	0.244	2.25	0.294	1.25	0.344	.67	0.394	.32	0.444	.15
0.145	5.73	0.195	3.85	0.245	2.22	0.295	1.24	0.345	.66	0.395	.32	0.445	.15
0.146	5.69	0.196	3.80	0.246	2.20	0.296	1.22	0.346	.66	0.396	.31	0.446	.15
0.147	5.65	0.197	3.76	0.247	2.17	0.297	1.20	0.347	.65	0.397	.30	0.447	.15
0.148	5.61	0.198	3.73	0.248	2.14	0.298	1.19	0.348	.64	0.398	.30	0.448	.15
0.149	5.57	0.199	3.69	0.249	2.12	0.299	1.17	0.349	.63	0.399	.29	0.449	.15
0.150	5.54	0.200	3.65	0.250	2.09	0.300	1.15	0.350	.63	0.400	.28	0.450	.15
0.151	5.50	0.201	3.62	0.251	2.07	0.301	1.14	0.351	.63	0.401	.28	-----	-----
0.152	5.46	0.202	3.58	0.252	2.04	0.302	1.12	0.352	.61	0.402	.27	-----	-----
0.153	5.42	0.203	3.55	0.253	2.02	0.303	1.11	0.353	.60	0.403	.26	-----	-----
0.154	5.38	0.204	3.51	0.254	2.00	0.304	1.10	0.354	.60	0.404	.25	-----	-----
0.155	5.34	0.205	3.48	0.255	1.97	0.305	1.08	0.355	.59	0.405	.25	-----	-----
0.156	5.30	0.206	3.44	0.256	1.94	0.306	1.07	0.356	.58	0.406	.25	-----	-----
0.157	5.26	0.207	3.40	0.257	1.92	0.307	1.06	0.357	.57	0.407	.25	-----	-----
0.158	5.22	0.208	3.36	0.258	1.89	0.308	1.04	0.358	.56	0.408	.24	-----	-----
0.159	5.18	0.209	3.32	0.259	1.87	0.309	1.03	0.359	.55	0.409	.24	-----	-----

TABLE 2.—Probable errors of single observations from individual curves

Date	Probable error $\pm$	Date	Probable error $\pm$
1939	cm.	1939	cm.
Oct. 17, a. m.	0.14	Oct. 20, p. m.	0.11
Oct. 18, a. m.	.10	Oct. 21, a. m.	.07
Oct. 19, a. m.	.10	Oct. 21, p. m.	.07
Oct. 19, p. m.	.05	Oct. 22, p. m.	.07
Oct. 20, a. m.	.04	Mean	1.05

<sup>1</sup> Probable error from plot of all observations, as shown in text, is  $\pm 0.19$  cm.

According to Harrison<sup>6</sup> the average amounts of precipitable water in a vertical atmospheric column over Washington, D. C., are as follows: Spring, 1.69 centimeters; summer, 3.49 centimeters; autumn, 2.23 centimeters; and winter, 1.00 centimeters. As all of our observations will be made through air masses greater than 1.0, the actual amounts of precipitable water measured will in general exceed these values. We found more consistent readings with larger air masses than with the sun near the zenith, which is explained in part by the fact that incipient clouds passing between the sun and instrument create much larger variations during a series when the sun is nearly overhead than when the sun is at a lower altitude, because the incipient cloud with its water content represents a larger percentage of the total water being measured and its slightest movement, unless it is absolutely uniform, alters the readings.

In table 3 are tabulated the original observations together with the times, air masses, reductions, factors, amounts of precipitable water through the observed air masses and the precipitable water reduced to unit air mass.

TABLE 3.—Reduction of water-vapor observations

BURRO MOUNTAIN, N. MEX.

SEPTEMBER 23, 1939

Time	Air mass	Readings	Factor	Ppt. H <sub>2</sub> O	Ppt. H <sub>2</sub> O 1.0 air mass
8:00 a. m.	2.47	209 101 310	0.326	1.35	0.55
8:14 a. m.	2.22	204 106 309	.341	1.19	.54
8:30 a. m.	2.02	204 109 314	.349	1.10	.54
8:40 a. m.	1.81	201 109 310	.352	.99	.55
9:14 a. m.	1.61	200 114 318	.367	.89	.55
9:33 a. m.	1.51	203 123 325	.376	.90	.60
10:12 a. m.	1.35	199 126 327	.390	.79	.69
11:10 a. m.	1.22	193 128 327	.404	.63	.52

SEPTEMBER 24, 1939

6:48 a. m.	6.18	230 69 279	0.177	5.12	0.83
6:58 a. m.	5.14	231 69 290	.203	4.50	.88
7:10 a. m.	4.21	227 65 299	.232	3.81	.90
7:29 a. m.	3.31	226 75 301	.249	2.85	.86
7:52 a. m.	2.52	227 84 315	.275	2.23	.88
9:37 a. m.	1.51	205 101 304	.328	1.51	1.00
9:56 a. m.	1.40	205 102 313	.339	1.49	1.06
11:04 a. m.	1.23	199 107 315	.369	1.25	1.02

SEPTEMBER 25, 1939

6:46 a. m.	6.96	276 40 317	0.128	Off table.	
6:58 a. m.	5.39	279 48 329	.149	5.93	1.10
7:07 a. m.	4.51	278 56 332	.165	4.50	1.00
7:18 a. m.	3.96	274 67 342	.198	3.81	.95
7:24 a. m.	3.53	273 65 341	.196	2.85	.81
8:01 a. m.	2.61	262 81 347	.241	2.23	.89
8:17 a. m.	2.30	256 89 347	.280	1.61	.69
8:39 a. m.	1.93	250 93 351	.280	1.49	.77
9:36 a. m.	1.51	235 110 353	.327	1.25	.83

SEPTEMBER 26, 1939

6:40 a. m.	7.87	261 35 297	0.120	Off table.	
6:48 a. m.	6.51	260 41 301	.136	6.55	1.01
7:00 a. m.	5.14	259 50 309	.162	5.40	1.05
7:12 a. m.	4.23	256 65 313	.179	4.72	1.12
7:30 a. m.	3.32	249 63 319	.211	3.67	1.11
8:00 a. m.	2.50	243 75 320	.238	2.87	1.15
8:32 a. m.	2.00	230 84 316	.270	2.27	1.14
9:35 a. m.	1.50	224 100 326	.311	1.66	1.11
10:51 a. m.	1.27	204 110 318	.353	1.39	1.09

<sup>6</sup> Harrison, Louis P. On the water-vapor in the atmosphere over the United States east of the Rocky Mountains. Mo. Wea. Rev. 59: 470. December, 1931.

TABLE 3.—Reduction of water-vapor observations—Continued

SEPTEMBER 27, 1939

Time	Air mass	Readings	Factor	Ppt. H <sub>2</sub> O	Ppt. H <sub>2</sub> O 1.0 air mass
				Cm.	Cm.
6:34 a. m.	0.30	259 36 204	0.121	Off table.	
6:47 a. m.	6.76	266 44 312	.145	6.18	0.91
6:56 a. m.	5.59	259 50 311	.165	5.35	.96
7:04 a. m.	4.77	258 57 316	.182	4.71	.98
7:15 a. m.	4.02	256 66 323	.206	3.81	.95
8:00 a. m.	2.82	238 87 329	.272	2.13	.85
8:35 a. m.	2.00	222 112 343	.344	1.27	.64
9:39 a. m.	1.50	217 114 337	.350	1.05	.70
11:18 a. m.	1.23	202 130 339	.398	.79	.64
1:39 p. m.	1.33	227 145 372	.390	.76	.57
3:45 p. m.	2.14	232 109 349	.313	1.21	.57
4:07 p. m.	2.51	237 99 344	.303	1.52	.61
4:27 p. m.	2.96	238 97 344	.299	1.66	.56
4:43 p. m.	3.52	245 90 345	.279	1.89	.54
4:57 p. m.	4.25	243 84 341	.269	2.27	.53
5:08 p. m.	5.14	239 75 321	.247	2.49	.48
5:18 p. m.	6.30	244 64 314	.215	3.36	.53
5:28 p. m.	7.98	246 57 300	.196	4.24	.53

SEPTEMBER 28, 1939

6:39 a. m.	8.46	234 85 323	0.271	2.23	.26
6:49 a. m.	6.72	233 92 325	.283	1.89	.28
7:03 a. m.	5.05	233 104 333	.304	1.34	.27
7:14 a. m.	4.18	226 109 337	.327	1.05	.25
7:35 a. m.	3.28	217 118 339	.356	.85	.26
8:04 a. m.	2.51	212 123 340	.372	.69	.27
8:36 a. m.	2.01	205 128 340	.391	.59	.29
9:41 a. m.	1.50	200 136 332	.401	.48	.32
11:25 a. m.	1.23	190 137 335	.426	.42	.34
1:33 p. m.	1.32	195 128 331	.404	.56	.42
3:17 p. m.	1.84	208 123 337	.377	.55	.30
3:52 p. m.	2.00	214 106 331	.343	.98	.49
3:46 p. m.	2.16	213 109 329	.346	.84	.39
4:07 p. m.	2.50	220 103 327	.323	1.19	.48
4:36 p. m.	3.26	231 89 324	.283	1.70	.52
4:55 p. m.	4.15	236 79 318	.254	2.53	.61
5:06 p. m.	5.02	240 69 309	.223	3.26	.65
5:18 p. m.	6.24	236 66 306	.224	3.51	.56
5:28 p. m.	8.12	231 56 302	.216	4.45	.54

1 Clouds during observation.

SEPTEMBER 29, 1939

6:37 a. m.	8.57	234 78 322	0.262	2.52	0.28
6:47 a. m.	6.96	234 83 326	.272	2.02	.29
7:02 a. m.	5.12	234 95 333	.293	1.59	.31
7:14 a. m.	4.21	222 94 321	.308	1.40	.33
7:32 a. m.	3.30	220 95 323	.310	1.20	.36
8:03 a. m.	2.51	213 103 325	.335	.97	.39
8:36 a. m.	2.01	203 113 328	.370	.73	.36
9:41 a. m.	1.50	192 125 323	.400	.58	.39
Mean.					.648

## TABLE MOUNTAIN, CALIF.

OCTOBER 17, 1939

6:56 a. m.	4.90	205 81 300	0.294	1.49	0.30
7:12 a. m.	3.88	186 77 275	.309	1.22	.31
7:37 a. m.	2.99	184 89 276	.330	.86	.29
8:03 a. m.	2.50	179 100 279	.358	.74	.30
8:41 a. m.	2.01	175 98 277	.364	.67	.33
10:05 a. m.	1.50	173 90 267	.347	.59	.39
11:42 a. m.	1.40	182 79 266	.296	.80	.57

OCTOBER 18, 1939

1:43 p. m.	1.67	196 81 277	0.292	1.19	0.66
2:05 p. m.	1.80	192 71 267	.275	1.28	.76
2:38 p. m.	1.99	211 79 283	.268	1.36	.68
2:49 p. m.	2.20	210 75 279	.258	1.53	.70
3:08 p. m.	2.49	208 68 276	.246	1.68	.67
3:32 p. m.	3.00	215 64 279	.231	1.90	.63
3:58 p. m.	4.00	214 60 274	.219	2.36	.59
4:14 p. m.	4.99	211 56 267	.210	2.83	.57
4:24 p. m.	5.93	212 53 269	.206	3.17	.53
4:34 p. m.	7.36	213 48 261	.184	3.86	.52

TABLE 3.—Reduction of water-vapor observations—Continued

OCTOBER 19, 1939

Time	Air mass	Readings	Factor	Ppt. H <sub>2</sub> O	Ppt. H <sub>2</sub> O 1.0 air mass
				Cm.	Cm.
6:36 a. m.	7.41	245 75 320	0.234	2.04	0.28
6:56 a. m.	4.97	238 96 338	.292	1.33	.27
7:12 a. m.	4.00	237 98 339	.297	1.05	.26
7:39 a. m.	3.00	217 99 322	.321	.83	.28
8:02 a. m.	2.80	224 101 328	.314	.70	.28
8:40 a. m.	2.01	224 109 327	.336	.57	.28
10:07 a. m.	1.50	202 112 318	.361	.57	.38
11:35 a. m.	1.39	212 110 324	.344	.66	.47
12:57 p. m.	1.50	186 94 286	.343	.77	.51
2:26 p. m.	2.00	193 88 283	.316	.93	.46
3:04 p. m.	2.49	192 83 275	.302	1.04	.42
3:33 p. m.	3.09	193 74 279	.293	1.32	.43
3:56 p. m.	4.02	197 68 271	.265	1.76	.44

OCTOBER 20, 1939

1:27 p. m.	1.61	207 108 315	0.343	0.75	0.47
2:27 p. m.	2.02	209 99 308	.321	.96	.47
3:04 p. m.	2.41	210 89 308	.302	1.26	.52
3:27 p. m.	3.00	213 83 300	.285	1.59	.53
3:54 p. m.	4.03	214 75 300	.274	2.22	.55
4:09 p. m.	5.01	212 67 289	.254	2.66	.53
4:19 p. m.	5.99	211 64 272	.228	3.20	.53
4:29 p. m.	7.44	215 59 270	.210	3.96	.53

OCTOBER 21, 1939

6:32 a. m.	9.35	213 55 272	.211	3.85	0.41
6:42 a. m.	7.21	213 67 284	.245	2.83	.39
6:58 a. m.	4.98	207 78 293	.284	1.93	.39
7:14 a. m.	3.98	206 84 296	.297	1.64	.41
7:42 a. m.	3.02	218 99 317	.312	1.11	.37
8:05 a. m.	2.50	202 99 305	.333	.85	.34
8:45 a. m.	2.01	193 111 308	.369	.64	.32
11:34 a. m.	1.41	184 109 298	.377	.42	.30
1:08 p. m.	1.55	188 100 296	0.356	0.49	0.32
2:22 p. m.	2.00	190 98 289	.336	.75	.38
3:25 p. m.	2.98	202 82 287	.292	1.24	.42
3:35 p. m.	3.29	206 76 283	.271	1.31	.40
3:51 p. m.	3.99	206 71 285	.267	1.59	.40
4:07 p. m.	4.95	207 69 280	.255	2.00	.40
4:17 p. m.	5.90	211 60 275	.227	2.43	.41
4:27 p. m.	7.10	219 50 276	.196	3.28	.46

OCTOBER 22, 1939

6:34 a. m.	8.90	215 57 276	.215	3.61	0.41
6:44 a. m.	6.80	214 67 283	.241	2.61	.38
7:00 a. m.	5.02	209 75 289	.271	1.85	.37
7:16 a. m.	4.05	208 80 294	.285	1.51	.37
7:44 a. m.	3.02	197 93 298	.330	1.00	.33
8:07 a. m.	2.49	204 90 300	.313	.97	.39

OCTOBER 23, 1939

1:28 p. m.	1.66	208 76 292	0.278	1.48	0.89
1:42 p. m.	1.72	208 77 294	.281	1.52	.88
2:29 p. m.	2.10	206 66 284	.259	1.87	.89
2:59 p. m.	2.50	216 63 289	.239	2.26	.90
3:21 p. m.	2.99	223 61 290	.223	2.61	.87
3:50 p. m.	3.97	221 58 283	.214	3.37	.85
4:05 p. m.	4.98	224 50 278	.188	4.01	.81
4:16 p. m.	5.93	224 47 271	.173	4.61	.78
4:26 p. m.	7.30	222 39 263	.153	5.40	.74
4:37 p. m.	9.71	185 23 206	.111	7.00	.72

OCTOBER 25, 1939

7:47 a. m.	3.06	184 127 322	0.419	0.27	0.09
8:13 a. m.	2.51	131 178 315	.429	.22	.09
8:34 a. m.	2.21	175 134 313	.437	.16	.07
8:52 a. m.	2.01	176 131 315	.434	.14	.07
9:19 a. m.	1.80	177 130 311	.247	.21	.12
9:31 a. m.	1.73	181 120 307	.405	.25	.14
Mean.					.406

\*The factors are obtained from the following formula:  $\frac{1}{4}(AC+AB-AC)/\frac{1}{4}(AB+BC+AC)$  where A=Crest; B the rho band and C the base line.

## ADVANTAGES IN THE NONUNIFORM HOUR OF OBSERVATION IN THE INTERPRETATION OF PUBLISHED PRECIPITATION DATA

By J. R. MILES

[Weather Bureau, Washington, D. C., October, 1939]

Hydrologists in their work must continually refer to rainfall records. Perhaps those most readily available, and hence most often used, are the published records of the cooperative and first-order stations of the Weather Bureau. The greater portion of these stations are maintained by unpaid volunteers, and the records of these cooperative stations are the foundation for most hydrologic studies.

The records, as prepared by the observer, include, among other data, the depth of precipitation in the 24 hours preceding the hour of observation, and in most instances the times of beginning and ending of each period of actual rainfall. In addition, those of the first-order stations show hourly depths. The published records of precipitation, however, show only the 24-hour depths and the time of observation. Since cooperative observers take observations at a time convenient to themselves, it follows that the hour is not uniform for all stations, but, in general, they fall into two groups: those taken in the evening near sunset, and those taken in the mornings shortly after sunrise. Exceptions to the above, however, are frequently noted, as, for example, the first-order stations, whose rainfall records indicate the midnight-to-midnight depths, and the river-rainfall stations, whose records usually indicate the precipitation in the 24 hours previous to 7 or 8 o'clock in the morning. This variation among the several stations is permitted by the Weather Bureau so long as the hour of observation is the same each day at a given station.

The cooperative observer records the observed data for each daily observation on a monthly record form in triplicate. The original sheets are on file at the various climatological section centers, the first carbon copy is bound and on file in the Central Office of the Weather Bureau, and the second carbon copy is retained by the observer himself. Similarly, disposition of the original record sheets of all other types of stations is such that they are not usually convenient to the hydrologist who may need the data on the more exact distribution of rainfall (times of beginning and ending, etc.); the various original records are the only sources of these data, and it may be inconvenient and expensive for him to consult them directly, hence the less detailed but more readily available published data must, in most instances, be the foundation for his studies.

It is usually true, however, that the hydrologist need not know the times of beginning and ending to the exact minute, or even the exact hour. If he knew, for example, that a 3-inch rain fell in the interval between sunset and midnight of a given day rather than from sunset of that day to sunset of the next day (as would be inferred from the record of a p. m. station), the record would be considerably enhanced and, for many hydrologic problems, sufficiently detailed.

The following discussion is intended as an aid in interpreting the published data, so that useful and more accurate approximations of rainfall intervals may be determined. It will be shown that the above-mentioned variation in the hour of observation between stations is an aid rather than a hindrance to the hydrologist under the present method of publication. While not so satisfactory as having access to the times of beginning and ending, it is nevertheless

quite often possible by this method to determine the portion of a day in which the rain began or ended.

The stations whose data are used as examples in this discussion are listed in table 1. The classification (a. m. station, p. m. station, or midnight station) of each has

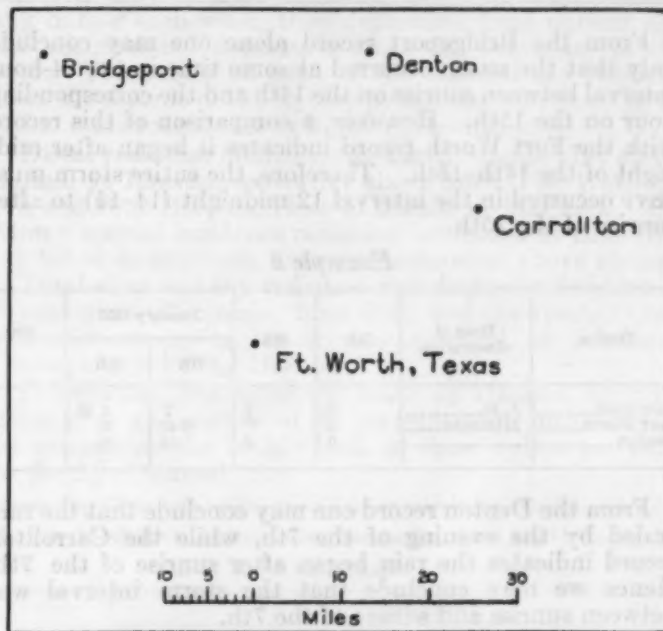


FIGURE 1.

reference to the approximate time of observation, and they will be referred to as such.

TABLE 1

Name	Classification	Time of observation
Bridgeport.....	A. m. station.....	After sunrise, probably 7 or 8 o'clock a. m.
Carrollton.....	A. m. station.....	After sunrise, probably 7 or 8 o'clock a. m.
Denton.....	P. m. station.....	Near sunset, probably 5 or 6 o'clock p. m.
Fort Worth.....	Midnight station.....	Has a recording rain gage but published daily totals reflect amount of precipitation in the 24 hours from midnight to midnight of the day for which precipitation is shown.

These stations are all in the Trinity River Basin, in eastern Texas. As shown by the following map (fig. 1), they are considered to be in sufficient proximity to each other to justify their use as examples in this discussion and to validate the soundness of the conclusions drawn.

In the following examples, all data are from the printed volume "Climatological Data, Texas Section, Monthly and Annual Summaries, 1930 to 1936," a publication of the United States Weather Bureau.

Examples 1, 2, and 3 represent short storm durations, with the data for the various stations so placed that, by a proper interpretation, one may determine the one-third part of the day in which the total storm occurred, i. e., midnight to a. m. (example 1), a. m. to p. m. (example 2), or p. m. to midnight (example 3).

Example 4 was selected to show how the data from

surrounding stations may be an aid to the hydrologist in interpreting the published data for a storm which occurred at a station during all or part of two or more successive observation days.

#### Example 1

Station	Hour of observation	August 1933		
		14th	15th	16th
Bridgeport.....	A. m.....	0	0.67	0
Fort Worth.....	Midnight.....	0	1.26	0
Denton.....	P. m.....	0	1.18	0

From the Bridgeport record alone one may conclude only that the storm occurred at some time in the 24-hour interval between sunrise on the 14th and the corresponding hour on the 15th. However, a comparison of this record with the Fort Worth record indicates it began after midnight of the 14th-15th. Therefore, the entire storm must have occurred in the interval 12 midnight (14-15) to after sunrise of the 15th.

#### Example 2

Station	Hour of observation	5th	6th	January 1935		9th
				7th	8th	
Carrollton.....	A. m.....	0	0	T	0.40	0
Fort Worth.....	Midnight.....	0	T	0.42	0	0
Denton.....		0	0	.54	0	0

From the Denton record one may conclude that the rain ended by the evening of the 7th, while the Carrollton record indicates the rain began after sunrise of the 7th. Hence we may conclude that the storm interval was between sunrise and sunset of the 7th.

#### Example 3

Station	Hour of observation	4th	June 1930		7th
			5th	6th	
Bridgeport.....	A. m.....	0	0	.25	0
Fort Worth.....	Midnight.....	0	0.55	0	0
Denton.....	Sunset.....	0	0	.52	0

In this storm it is noted that the rain ceased by midnight of the 5th-6th, because Fort Worth recorded none after that time. It must have started raining after sunset of the 5th, because Denton had received none before that time. Hence we may conclude that it fell in the interval between sunset of the 5th and midnight of the 5th-6th.

#### Example 4

Station	Hour of observation	March 1933			
		4th	5th	6th	7th
Bridgeport.....	A. m.....	0	0.81	1.02	0
Fort Worth.....	Midnight.....	0	1.60	0	0
Denton.....	P. m.....	0	1.93	0	0

From the Bridgeport record it is evident that the rain fell some time in the 48 hours from after sunrise on the

4th to after sunrise on the 6th. However, comparison with the Fort Worth record indicates that the interval was 24 hours or less, and confined between midnight of the 4th-5th, and midnight of the 5th-6th.

Now, the Denton record indicates that the precipitation must have ceased previous to sunset of the 5th. Thus we have shortened the maximum-possible storm period of 48 hours to a maximum-probable period of 18 hours between midnight of the 4th-5th and sunset of the 5th.

The data in example 4 are now considered with the purpose of constructing a mass curve of precipitation for the station at Bridgeport.

Curve ADG (fig. 2) may be considered the limiting mass curve of precipitation if data for the Bridgeport station alone were available. However, the nearby a. m. station at Denton had received no rain before observation

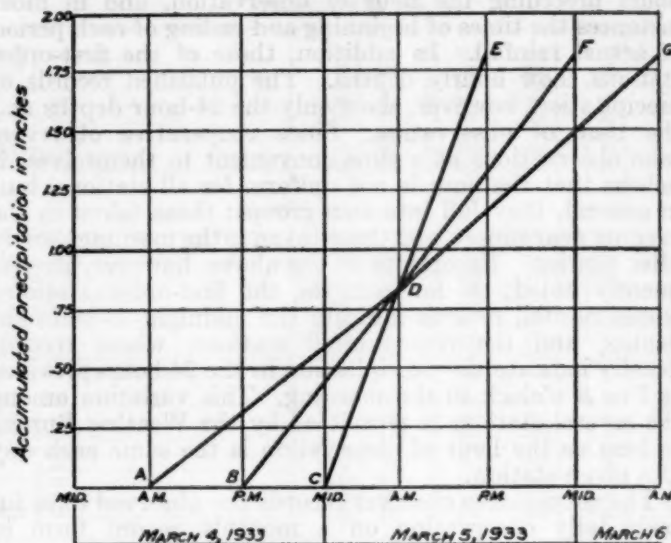


FIGURE 2.

time on the 4th, and the compatibility of the two records justifies the inference that the reach BD is preferable to AD. Similarly, the record for the midnight station at Fort Worth indicates that there had been no rain at that station before midnight of the 4th-5th, and so it follows that CD is the more nearly correct reach than either AD or BD.

Reach DG is superseded by DF when one considers the fact that Fort Worth shows no rain after midnight of the 5th-6th; and the p. m. station at Denton shows no rain to have fallen after its observation time on the 5th, thus further restricting the period of rainfall, and giving preference to the reach DE rather than either DF or DG.

The final limiting mass curve CDE is obviously to be preferred to the curve ADG and is probably the best that can be drawn from the data at hand.

#### CONCLUSION

By a juxtaposition of the 24-hour precipitation records of nearby stations of varying times of observation, the maximum probable period of precipitation for a given storm will, in many cases, be considerably shorter than that possible to be determined if all stations took observations at a uniform hour.

## SOLAR OBSERVATIONS

[Meteorological Research Division, EDGAR W. WOOLARD in charge]

## SOLAR RADIATION OBSERVATIONS, APRIL 1940

By DAVID HABER

Measurements of solar radiant energy received at the surface of the earth are made at nine stations maintained by the Weather Bureau, and at ten cooperating stations maintained by other institutions. The intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) at all these stations by self-registering instruments; pyrheliometric measurements of the intensity of direct solar radiation at normal incidence are made at frequent intervals on clear days at three Weather Bureau stations (Washington, D. C., Madison, Wis., Lincoln, Nebr.) and at the Blue Hill Observatory at Harvard University. Occasional observations of sky polarization are taken at the Weather Bureau stations at Washington and Madison.

The geographic coordinates of the stations, and descriptions of the instrumental equipment, station exposures, and methods of observation, together with summaries of the data obtained, up to the end of 1936, will be found in the MONTHLY WEATHER REVIEW, vol. 65, December 1937, pp. 415 to 441; further descriptions of instruments and methods are given in Weather Bureau Circular Q.

Table 1 contains the measurements of the intensity of direct solar radiation at normal incidence, with means and their departures from normal (means based on less than 3 values are in parentheses). At Madison and Lincoln the

observations are made with the Marvin pyrheliometer; at Washington and Blue Hill they are obtained with a recording thermopile, checked by observations with a Marvin pyrheliometer at Washington and with a Smithsonian silver disk pyrheliometer at Blue Hill. The table also gives vapor pressures at 7:30 a. m. and at 1:30 p. m. (75th meridian time).

Table 2 contains the average amounts of radiation received daily on a horizontal surface from both sun and sky during each week, then departures from normal and the accumulated departures since the beginning of the year. The values at most of the stations are obtained from the records of the Eppley pyrheliometer recording on either a microammeter or a potentiometer.

Direct radiation intensities averaged considerably above normal at Lincoln, somewhat above normal at Washington and Blue Hill, and close to normal at Madison. The March normal incidence radiation intensities at Blue Hill, published as late data, averaged somewhat above normal.

Total solar and sky radiation was decidedly deficient at Washington, Riverside, Blue Hill, and Newport. Considerable excess radiation was received at Madison, Chicago, and Friday Harbor.

Polarization measurements made at Madison on three dates give an average of 60 percent, with maximum of 66 percent on the 20th. Both of these values are close to the April normal.

TABLE 1.—Solar radiation intensities during April 1940

[Gram-calories per minute per square centimeter of normal surface]

## WASHINGTON, D. C.

Date	Sun's zenith distance										Local mean solar time
	7:30 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	1:30 p. m.
	Air mass										
	A. M.					P. M.					
	e	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e
Apr. 4	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Apr. 6	7.04				0.74						8.81
Apr. 10	2.26				1.23	1.06					2.49
Apr. 11	4.57				.90						4.17
Apr. 15	6.76				1.08						7.04
Apr. 25	6.02				.82						5.16
Apr. 26	5.36				1.02						3.99
Apr. 29	5.79	0.91	1.07	1.28	1.49						3.15
Means		(.91)	(1.07)	1.01	(1.58)						
Departures		+.12	+.18	-.06	+.21						

## MADISON, WIS.

Apr. 1	3.63	0.58	0.79	0.93	0.90	1.32					4.37
Apr. 5	3.15	.96	1.06	1.21	1.38	1.54	1.37				3.30
Apr. 9	4.17			1.19	1.26	1.45					4.75
Apr. 12	2.06	.79	.94	1.06	1.15	1.35					2.49
Apr. 13	2.62	.98	1.14	1.30							2.36
Apr. 18	4.37						1.24				5.79
Apr. 19	4.75		.70	.83	1.04	1.26					5.36
Apr. 20	3.81		1.04	1.15	1.34	1.52					2.87
Apr. 26	4.17		.91	1.03	1.16	1.40					4.95
Apr. 27	3.45	.77	.88	.99	1.01	1.38					3.81
Means		.82	.93	1.06	1.15	1.40	(1.30)				
Departures		.00	-.01	+.03	-.06	-.04	+.11				

## LINCOLN, NEBR.

Apr. 3	3.45		1.13	1.26	1.42		1.33	1.15	0.92	0.83	2.49
Apr. 4	3.16		1.14	1.25		1.60	1.33	1.15	0.92	0.83	2.87
Apr. 12	1.58		1.05			1.68	1.34				1.24
Apr. 13	2.62			1.11	1.33						2.36
Apr. 18	3.63	0.83	.80	.79	1.00		1.24	1.04			4.37
Means		(.83)	1.03	1.10	1.25	(1.64)	1.30	(1.10)	(.92)	(.83)	
Departures		+.11	+.20	+.12	+.06	+.18	+.12	+.14	+.09	+.13	

TABLE 1.—Solar radiation intensities during April 1940—Continued

## BLUE HILL, MASS.

Date	Sun's zenith distance										Local mean solar time
	7:30 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	1:30 p. m.
	Air mass										
	A. M.					P. M.					
	e	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e
Apr. 6	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Apr. 7	2.2	0.94	1.02	1.12	1.28	1.44	1.32	1.08	1.05	1.02	2.8
Apr. 10	2.0	1.00	1.09	1.21	1.35	1.54	1.25	1.08	.96	.85	1.6
Apr. 11	3.6	.75	.87	1.06	1.21	1.47	1.25	1.08	.96	.85	2.8
Apr. 14	4.0	.89	.97	1.09	1.25	1.43					2.9
Apr. 15	2.0	.84	.97	1.06	1.24	1.48					1.5
Apr. 19	2.6	.89	.99	1.11	1.26	1.40					2.5
Apr. 20	5.6					1.38					4.6
Apr. 26	5.2	.78	.88	1.03		1.46					4.4
Apr. 28	3.0	.81	.92	1.06	1.26	1.49	1.28	1.10	.98	.88	2.8
Apr. 29	3.0					1.03	.84	.70	.61	.29	
Means		.86	.96	1.10	1.26	1.45	1.22	1.01	.88	.78	
Departures		-.01	.00	.09	+.06	+.06	+.09	+.01	-.02	+.04	

1 Extrapolated.

2 Partial eclipse; not used in obtaining means.

## LATE DATA

## BLUE HILL, MASS.

Mar. 1	2.2						0.89	0.81	0.72	3.0	
Mar. 2	1.5	.96	1.07	1.16		1.44	1.39	1.14	1.07	2.5	
Mar. 8	2.8			.98	1.17					3.2	
Mar. 9	3.0	.78	.88	1.03	1.23	1.45	1.26	1.11	.97	3.5	
Mar. 10	2.2	.87	1.03	1.18	1.33	1.44	1.25		.90	2.1	
Mar. 11	1.6	.99	1.05	1.21	1.37	1.55	1.39	1.24	1.08	1.6	
Mar. 12	1.0	1.05	1.14	1.30	1.41	1.66	1.40	1.23	1.12	1.8	
Mar. 13	1.3	1.02	1.11	1.22	1.35	1.53	1.32	1.13	1.00	1.9	
Mar. 15	6.2	.72	.87	1.00	1.17	1.36				6.1	
Mar. 17	2.6				1.23					2.9	
Mar. 18	2.1	.94	1.01	1.11	1.24	1.39				2.5	
Mar. 19	4.6	1.00	1.10	1.19	1.32	1.48				8.0	
Mar. 21	2.3				1.46		1.30	1.16	1.04	.95	2.2
Mar. 23	1.1	.97	1.05	1.20	1.36	1.53				1.2	
Mar. 24	1.1		.94	1.10	1.27	1.50	1.35	1.18	1.05	.97	1.3
Mar. 25	1.3		1.03	1.20	1.34	1.47					1.5
Mar. 26	2.0	.94	1.04	1.16		1.56	1.34	1.10	.98	.90	2.4
Means		.93	1.03	1.15	1.29	1.48	1.33	1.13	1.01	.91	---
Departures		+.04	+.06	+.06	+.06	+.05	+.10	+.07	+.05	+.05	---

TABLE 2.—Average daily totals of solar radiation (direct + diffuse) received on a horizontal surface

[Gram-calories per square centimeter]

Week beginning—	Wash- ington	Madi- son	Lin- coln	Chi- cago	New York	Fresno	Albu- querque	La Jolla	Miami	New Orleans	River- side	Blue Hill	New- port	Friday Harbor	Cam- bridge
Apr. 1.....	cal. 418	cal. 343	cal. 433	cal. 350	cal. 437	cal. 531	cal. 478	cal. 507	cal. 525	cal. 376	cal. 439	cal. 449	cal. 467	cal. 410	cal. 436
Apr. 8.....	314	404	522	270	368	581	713	-----	490	507	540	318	353	457	329
Apr. 15.....	166	526	487	377	143	593	585	-----	490	362	554	233	271	496	224
Apr. 22.....	458	450	249	498	498	537	575	487	450	406	305	417	436	387	433

## DEPARTURES FROM WEEKLY NORMALS

Apr. 1.....	+49	-26	+23	+57	+110	+11	-----	-15	+58	-4	-45	+71	+67	+70	-----
Apr. 8.....	-80	+2	+77	-70	+38	+7	-----	-----	+16	+93	+52	-23	-49	+127	-----
Apr. 15.....	-247	+127	+34	+40	-208	-3	-----	-----	+20	-53	+22	-139	-135	+51	-----
Apr. 22.....	+12	+25	-189	+129	+82	-36	-----	-24	-27	+11	-153	-26	-20	-97	-----

## ACCUMULATED DEPARTURES ON APR. 29, 1940

	-679	+1,512	-3,794	+1,365	+2,842	-2,037	-----	-1,540	+2,674	+1,841	-3,339	+840	-126	+2,821	-----
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## LATE DATA

The mean daily total solar and sky radiation in gram-calories per square centimeter received on a horizontal surface at Fairbanks for the weeks beginning Feb. 26, March 4, 11, 18, and 25 are respectively 143, 153, 154, 305, and 279, with corresponding departures +3, -8, -45, +96, and -11. Similar means for Miami and for the above dates are, respectively, 478, 418, 375, 498, and 408, with corresponding departures +92, +33, -41, +35, and -48.

## POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.), Superintendent, U. S. Naval Observatory. Data from measurements at the U. S. Naval Observatory from plates obtained at the observatories indicated. Difference in longitude is measured from the central meridian, positive toward the west. Latitude is positive toward the north. Areas are corrected for foreshortening and expressed in millionths of Sun's hemisphere. For each day below longitude, latitude, area of spot or group, and spot count, are given, respectively, the assumed longitude of the center of the disk, assumed latitude of the center of the disk, total area of spots and groups, and total spot count.]

Date	East- ern stand- ard time	Mount Wil- son group No.	Heliographic	Area of spot or group	Spot count	Plate qual- ity	Observatory
			Dif- fer- ence in lon- gi- tude	Lon- gi- tude	Lat- i- tude	Dis- tance from cen- ter of disk	
1940 Apr. 1...	A. M. 13 33	(*)	°	°	°	°	
		6799	-59	352	-19	59	12
		6794	-8	43	-12	10	218
		6795	-4	47	-11	5	24
		6792	+11	62	+7	17	48
		6792	+19	70	+7	24	194
		6796	+49	100	-5	49	194
		6794	+75	126	+11	77	242
			(51)	(-7)		1,017	33
Apr. 2...	14 26	6800	-58	329	+8	61	6
		6799	-39	358	-15	40	66
		(*)	+5	42	-4	5	24
		6794	+7	44	-12	10	230
		6795	+10	47	-11	11	36
		6792	+23	60	+8	27	48
		6792	+32	69	+8	35	145
		6796	+39	76	+20	47	24
		6796	+62	90	-5	62	194
			(37)	(-6)		773	66
Apr. 3...	10 51	6800	-44	342	+8	49	12
		6801	-38	348	-7	38	97
		6799	-28	358	-15	30	73
		6798	-19	7	+24	36	12
		6794	+19	45	-12	20	242
		6795	+21	47	-11	21	48
		6792	+44	70	+8	48	121
		6796	+52	78	+20	59	24
		6796	+74	100	-5	74	194
			(26)	(-6)		823	41
Apr. 4...	11 3	6801	-25	347	-7	25	170
		6799	-16	356	-15	18	73
		6794	+31	43	-12	31	242
		6794	+31	43	-14	32	24
		6795	+34	46	-10	34	24
		6792	+58	70	+8	61	85
		(*)	+80	92	+12	82	12
			(12)	(-6)		630	48

See notes at end of table.

## POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	East- ern stand- ard time	Mount Wil- son group No.	Heliographic	Area of spot or group	Spot count	Plate qual- ity	Observatory
			Dif- fer- ence in lon- gi- tude	Lon- gi- tude	Lat- i- tude	Dis- tance from cen- ter of disk	
1940 Apr. 5...	A. M. 11 44	6804	-85	274	-10	85	48
		6801	-13	346	-7	13	48
		6801	-9	350	-8	10	170
		6799	-3	356	-15	10	194
		(*)	-3	356	-11	6	12
		6803	+8	7	-6	8	12
		6794	+45	44	-11	45	218
		6795	+48	47	-10	48	6
		6792	+71	70	+8	75	24
			(359)	(-6)		732	41
Apr. 6...	11 8	6803	-75	271	-10	75	194
		6801	0	346	-7	1	48
		6799	+1	347	-15	10	24
		6801	+5	351	-8	5	194
		6799	+10	356	-15	13	170
		6803	+22	8	-6	22	24
		6794	+58	44	-12	58	242
			(346)	(-6)		896	33
Apr. 7...	12 30	6803	-68	264	-10	68	73
		6803	-53	279	-10	53	145
		6804	-40	292	+19	48	12
		6801	+14	346	-7	14	48
		6801	+20	352	-9	21	194
		6799	+23	355	-16	25	73
		6794	+71	43	-12	71	242
			(332)	(-6)		787	27
Apr. 8...	10 58	6803	-43	277	-9	43	145
		6805	-43	277	+22	51	48
		6805	-40	280	+20	40	73
		6801	+34	354	-9	34	145
		6799	+37	357	-17	39	48
		6802	+49	9	-8	49	24
		6794	+85	43	-12	85	242
			(320)	(-6)		725	25
Apr. 9...	13 40	6808	-86	219	-12	86	12
		6805	-30	275	+22	42	36
		6803	-29	276	-9	29	97
		6805	-26	279	+20	37	48
		6807	+42	347	+8	45	73
		6801	+48	353	-8	48	97
		6806	+50	355	+7	53	12
		6801	+54	359	-7	54	6
		6802	+63	8	-7	63	6
			(305)	(-6)		387	32

## POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	East- ern stand- ard time	Mount Wil- son group No.	Heliographic Dif- fer- ence in longi- tude	Lon- gi- tude	Latitude	Dis- tance from center of disk	Area of spot or group	Spot count	Plate qual- ity	Observatory
1940 Apr. 10..	A. M. 11 27	6808	-72	221	-12	72	24	4	F	U. S. Naval.
		6803	-27	266	-11	27	73	6		
		6803	-17	276	-10	18	145	10		
		6805	-13	280	+19	28	73	7		
		6807	+55	348	+9	59	242	7		
		6801	+61	354	-9	61	97	1		
		6806	+64	357	+7	68	97	5		
				(203)	(-6)		751	40		
Apr. 11..	11 28	6808	-50	221	-12	50	194	12	G	Do.
		6803	-13	267	-11	14	48	6		
		6803	-3	277	-10	5	97	7		
		6805	-1	279	+18	24	48	4		
		6807	+69	349	+9	72	242	6		
		6801	+75	355	-9	75	97	1		
		6806	+79	359	+6	80	48	1		
				(280)	(-6)		774	37		
Apr. 12..	9 25	6808	-46	222	-12	46	388	43	VG	Mt. Wilson.
		6809	-23	245	-3	24	36	5		
		6803	+3	271	-10	5	12	3		
		6803	+9	277	-11	10	97	9		
		6807	+84	352	+8	85	242	3		
				(268)	(-6)		775	63		
Apr. 13..	10 50	6810	-88	166	-7	88	97	1	VG	U. S. Naval.
		6808	-33	221	-12	33	242	46		
		6809	-8	246	-3	9	6	3		
		6803	+22	276	-10	22	48	19		
				(254)	(-6)		393	69		
Apr. 14..	11 53	6810	-74	166	-7	74	145	3	VG	Do.
		6813	-58	182	+20	66	24	1		
		6808	-19	221	-13	20	339	40		
		6812	-18	222	-24	25	48	2		
		6809	+6	246	-3	6	24	6		
		6811	+22	262	-10	22	6	1		
		6803	+36	276	-9	36	48	10		
				(240)	(-6)		634	63		
Apr. 16..	10 37	6814	-76	138	+15	78	97	3	G	Do.
		6814	-60	145	+11	71	291	1		
		6810	-46	168	-6	46	97	3		
		6808	+6	220	-13	10	485	40		
		6812	+9	223	-22	12	48	4		
		(*)	+14	228	+19	27	12	1		
		6803	+64	278	-9	64	12	1		
				(214)	(-5)		1042	53		
Apr. 17..	10 54	6817	-80	121	+13	83	24	11	G	Mt. Wilson.
		6816	-75	126	+7	76	73	1		
		6814	-56	145	+12	56	194	9		
		6810	-32	169	-6	32	73	5		
		6808	+19	220	-13	21	291	32		
		6812	+22	223	-22	28	12	3		
		6815	+58	259	-17	59	12	2		
				(201)	(-5)		679	63		
Apr. 18..	9 44	6818	-88	100	-4	88	97	1	G	Do.
		6817	-67	121	+13	70	73	5		
		6816	-61	127	+7	63	24	1		
		6814	-80	138	+13	83	97	13		
		6814	-43	145	+12	46	194	9		
		6810	-19	169	-6	19	73	5		
		6808	+33	221	-12	34	291	27		
		6815	+69	257	-17	70	12	1		
				(188)	(-5)		861	62		
Apr. 19..	12 16	6818	-74	100	-4	74	48	1	P	Do.
		6817	-53	121	+13	55	48	2		
		6816	-48	126	+7	50	12	3		
		6814	-35	139	+13	39	48	9		
		6814	-29	145	+11	33	170	5		
		6810	-5	169	-6	4	61	4		
		6808	-48	126	-12	46	97	3		
		6819	+32	226	+1	52	61	3		
				(174)	(-5)		545	30		
Apr. 20..	9 0	6821	-84	78	+5	85	48	2	VG	Do.
		6818	-60	102	-4	60	170	1		
		6820	-57	105	-20	62	12	3		
		6817	-47	115	+13	50	48	16		
		6817	-40	122	+13	44	73	4		
		6816	-35	127	+7	37	12	6		

See notes at end of table.

## POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	East- ern stand- ard time	Mount Wil- son group No.	Heliographic Dif- fer- ence in longi- tude	Lon- gi- tude	Latitude	Dis- tance from center of disk	Area of spot or group	Spot count	Plate qual- ity	Observatory
1940 Apr. 20..	A. M.	6814	-23	139	+15	30	73	30		Mt. Wilson.
		6814	-17	145	+11	24	218	3		
		6810	+8	170	-6	8	73	9		
		6808	+61	223	-12	61	61	4		
		6819	+66	228	+2	66	97	7		
				(162)	(-5)		885	85		
Apr. 21..	12 40	6821	-68	79	+5	69	48	1	VG	Do.
		6818	-47	100	-4	47	170	1		
		6817	-53	114	+13	53	97	25		
		6817	-27	120	+12	32	73	3		
		6816	-22	125	+7	25	48	8		
		6814	-10	137	+15	22	73	25		
		6814	-3	144	+11	16	242	13		
		6822	+8	155	-11	10	18	2		
		6810	+23	170	-5	23	61	6		
		6808	+72	219	-12	72	24	1		
		6819	+80	227	+1	80	48	2		
				(147)	(-5)		902	87		
Apr. 22..	13 39	6821	-54	79	+5	55	12	1	VG	U. S. Naval.
		6818	-32	101	-4	32	170	1		
		6817	-18	115	+13	25	121	23		
		6817	-12	121	+12	20	48	1		
		6816	-8	125	+8	10	48	11		
		6814	+9	142	+15	20	48	17		
		6814	+11	144	+11	12	194	1		
		6822	+20	153	-11	21	12	5		
		6810	+37	170	-5	37	48	10		
		6823	+44	177	+9	46	24	7		
				(133)	(-5)		726	77		
Apr. 23..	11 27	6821	-40	81	+5	42	12	1	F	Do.
		6818	-20	101	-4	20	162	1		
		6817	-6	115	+13	18	194	14		
		6817	+1	122	+12	17	48	1		
		6817	+6	127	+10	16	97	6		
		6814	+23	144	+12	28	48	11		
		6814	+23	144	+10	27	218	1		
		(*)	+26	147	-11	27	12	1		
		6810	+49	170	-5	49	24	4		
		6823	+58	179	+9	61	48	4		
				(121)	(-5)		883	44		
Apr. 24..	17 15	(*)	-41	64	+10	44	48	4	VG	Do.
		6818	-4	101	-4	5	194	1		
		6817	+10	115	+13	21	97	13		
		6817	+16	121	+11	23	12	1		
		(*)	+21	126	-32	34	48	9		
		6814	+40	145	+11	43	12	1		
		6814	+40	145	+10	43	194	1		
		(*)	+42	147	-11	43	73	10		
				(105)	(-5)		678	40		
Apr. 25..	13 57	6824	-73	20	+11	75	242	6	F	Do.
		(*)	-12	81	-3	12	12	1		
		6818	+8	101	-2	9	36	7		
		6818	+9	102	-3	9	194	1		
		6817	+25	118	+14	31	12	2		
		6814	+51	144	+10	63	194	1		
		(*)	+53	146	-10	63	61	4		
		(*)	+58	151	-8	68	48	2		
				(93)	(-5)		799	24		
Apr. 26..	16 5	(*)	-70	9	-7	70	6	1	VG	Do.
		6824	-58	21	+11	58	194	7		
		(*)	+2	81	+5	10	6	4		
		(*)	+20	99	-2	20	12	6		
		6818	+22	101	-4	22	145	1		
		(*)	+40	139	+13	63	73	6		
		6814	+66	145	+10	68	194	1		
		(*)	+67	146	-10	67	170	5		
		(*)	+73	152	-9	73	97	1		
				(79)	(-5)		897	32		
Apr. 27..	10 58	6824	-48	21	+11	49	145	4	VG	Do.
		6824	-43	26	+11	46	12	6		
		6818	+34	103	-4	34	145	1		
		6817	+49	118	+14	52	48	11		
		(*)	+70	139	+11	72	24	6		
		(*)	+70	139	+13	73	24	6		
		6814	+78	147	+10	79	194	1		
		(*)	+81	150	-11	81	194	3		
				(69)	(-4)		786	36		

## POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	East- ern stand- ard time	Mount Wilson group No.	Heliographic				Area of spot or group	Spot count	Plate qual- ity	Observatory
			Dif- ference in longi- tude	Lon- gi- tude	Lat- tude	Dis- tance from cen- ter of disk				
Apr. 28..	A m 10 58	6824	-35	20	+9	38	145	6	P	Mt. Wilson.
		6818	+48	103	-4	48	121	5		
		6817	+63	118	+13	66	73	4		
		6814	+85	140	+14	86	48	2		
		(55)	(-4)		387	17				
Apr. 29..	13 3	6824	-22	19	+9	25	121	5	F	Do.
		6818	+62	103	-4	62	121	8		
		6817	+76	117	+14	77	24	2		
		(41)	(-4)		266	15				
Apr. 30..	10 50	6824	-0	20	+10	17	121	13	G	Do.
		6825	+2	31	-13	9	24	6		
		6818	+73	102	-3	73	97	4		
		(29)	(-4)		242	23				

† Mean daily area for 29 days=713.

\* Not numbered.

Plate quality: VG=very good; G=good; F=fair; P=poor.

## PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR APRIL 1940

[Dependent alone on observations at Zurich, Switzerland]

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich]

April 1940	Relative numbers	April 1940	Relative numbers	April 1940	Relative numbers
1.....	Ec 85	11.....	a 50	21.....	a 94
2.....	a 80	12.....	53	22.....	83
3.....	Ec —	13.....	53	23.....	a 63
4.....	47	14.....	d 60	24.....	Wc 64
5.....	a 62	15.....	74	25.....	ad 56
6.....	ad 58	16.....	ad 65	26.....	50
7.....	64	17.....	65	27.....	62
8.....	56	18.....	59	28.....	38
9.....	Wc 41	19.....	Wcd 71	29.....	32
10.....	Ec 59	20.....	a 79	30.....	35

Mean, 29 days=60.6

a= Passage of an average-sized group through the central meridian.

b= Passage of a large group through the central meridian.

c= New formation of a group developing into a middle-sized or large center of activity; E, on the eastern part of the sun's disk; W, on the western part; M, in the central-circle zone.

d= Entrance of a large or average-sized center of activity on the east limb.

## AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE in charge]

By B. FRANCIS DASHIELL

April weather was abnormally cool east of the Rocky Mountains, while surface temperatures were above normal in the far West. Over the former area the resultant-wind directions at 1.5 and 3 kilometers (charts VIII and IX) were decidedly northwesterly. These winds were more northerly than normal. At Fargo, N. Dak., for instance, the resultant direction at 1.5 kilometers was oriented  $51^\circ$  north, or clockwise of normal. Also, those sections of the country with large negative departures of surface temperature during April were characterized by outstanding northerly departures of resultant-wind directions from normal. However, the resultant velocities were less than normal over all but the southern portion of the United States.

In agreement with the pronounced negative departures from normal of monthly mean surface temperatures since the beginning of last winter, the upper-air resultant-wind directions have been consistently more northerly than normal over the areas where such temperature departures prevailed.

Comparison of the 5 p. m. with the 5 a. m. winds at 1.5 and 3 kilometers indicated definite diurnal variations. The afternoon resultant directions were more southerly than the early morning directions over all of the country except in the northern Rocky Mountain region at 1.5 and 3 kilometers and the South and Southeast at 1.5 kilometers. Large diurnal changes were outstanding in the Central States where the 5 p. m. winds departed in counter clockwise rotations from the 5 a. m. directions by as much as  $47^\circ$ ,  $34^\circ$ ,  $33^\circ$ , and  $26^\circ$  at St. Louis, Mo., Nashville, Tenn., Chicago, Ill., and Cincinnati, Ohio, respectively at 1.5 kilometers. At Brownsville, Tex., Mobile, Ala., and Miami, Fla., respectively, the 5 p. m. winds were more northerly than the 5 a. m. by  $118^\circ$ ,  $34^\circ$ , and  $48^\circ$ . Diurnal variations were not so marked at 3 kilometers. The 5 p. m. resultant-wind velocities were lower than at 5 a. m. almost generally, except over the Southeast and far Northwest.

Mean barometric pressure during April was lowest at 5,000 feet (chart VIII) over Mount Washington, N. H. (837.1 millibars), while at all higher levels (table 1) the lowest mean pressure was centered over Sault Ste. Marie, Mich., and highest over Miami, Fla. Mean pressures were higher than during March at all radiosonde stations shown in table 1. At 8 kilometers, where maximum monthly changes took place, the largest increase of pressure over the preceding month (10 millibars) occurred at Sault Ste. Marie, Mich., and the smallest (1 millibar) over Miami, Fla., and the Pacific slope.

During April the steepest gradient between the low and high areas over Sault Ste. Marie, Mich., and Miami, Fla., respectively, occurred at 8 kilometers. The greatest

concentration of isobars existed over the East, particularly the Middle and South Atlantic States, where resultant-wind velocities were outstanding at 8 kilometers (23.9 m. p. s. from the WNW at Atlanta, Ga., and 24.6 m. p. s. from the W. at Miami, Fla., respectively).

April was warmer than March in the United States and Alaska at all levels up to 9 kilometers, and colder above at all higher levels. This situation was more pronounced over the entire Mississippi valley. However, in the Southwest and far Northwest, where surface mean temperatures were decidedly above normal, the mean temperatures at all standard levels up to an average of 18 kilometers were higher in April than during March.

At Oakland, Calif., and Washington, D. C., the mean temperatures at all levels were lower in April 1940 than during the corresponding month of 1939. The current mean temperature over Nashville, Tenn., Oklahoma City, Okla., Omaha, Nebr., and Sault Ste. Marie, Mich., was higher than in April 1939 at all levels up to 7 kilometers, and then colder above.

The surface of mean freezing temperature in the upper air sloped up toward the South from an altitude of 640 meters above mean sea level at Sault Ste. Marie, Mich., to 4,280 meters in height over Miami, Fla. At the latter place this was an increase of 200 meters over the preceding month. This surface of mean freezing temperature also was lower over the Atlantic coast than the Pacific, increasing in height from 2,330 meters at Norfolk, Va., to 3,040 meters over Oakland, Calif.

The lowest temperatures observed during the month occurred at 13 kilometers over the entire country north of the 36th parallel, and at progressively greater heights farther south, reaching a maximum altitude of 18 kilometers over Miami, Fla. The lowest minimum temperature observed in April was  $-78.0^\circ$  C. over Miami, Fla., and the highest minimum was  $-66.1^\circ$  C. over Minneapolis, Minn.

MEAN MONTHLY ISENTROPIC CHART<sup>1</sup>

The mean isentropic chart,  $\theta=304^\circ$ , for April 1940 (chart XII), showed three anticyclonic eddies. One was situated over northwestern Mexico, another in the western Gulf region, and the third somewhere off the south Atlantic coast. None of these eddies was centered in the network of stations shown on the chart, but they were indicated quite clearly by the corresponding moist tongues. The two moist tongues over the Continent seemed to be responsible for the precipitation centers to the west of the Appalachians and in Montana and the Dakotas.

<sup>1</sup> Prepared by Division of Education and Research.

TABLE 1.—Mean free-air barometric pressure (P.) in millibars, temperature (T.) in degrees centigrade, and relative humidities (R. H.) in percent obtained by airplanes and radiosondes during April 1940

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																											
	Albuquerque, N. Mex. (1,620 m.)				Atlanta, Ga. (300 m.)				Billings, Mont. (1,089 m.)				Bismarck, N. Dak. (505 m.)				Boise, Idaho (864 m.)				Buffalo, N. Y. (220 m.)				Charleston, S. C. (14 m.)			
	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.
Surface.....	30	836	10.7	36	30	981	12.7	72	28	891	4.4	70	30	957	2.0	84	29	915	8.3	72	28	980	2.0	81	29	1,015	13.1	80
500.....					30	958	13.1	67					30	900	2.0	79	29	900	8.5	67	28	955	2.6	71	29	958	14.0	65
1,000.....					30	902	11.2	64					30	846	-0.2	77	29	847	7.6	61	28	898	3.3	69	29	903	11.7	59
1,500.....					30	850	8.3	62	28	846	4.5	72	30	794	-2.7	80	29	797	3.8	63	28	843	-2.4	67	29	850	8.7	56
2,000.....	30	798	10.2	36	30	800	6.3	58	28	795	2.3	68	30	746	-4.0	75	29	748	0.6	65	28	792	-4.8	64	29	800	6.7	53
2,500.....	30	751	7.1	38	30	752	4.1	55	28	747	-0.6	67	30	700	-6.2	71	29	703	-3.4	68	28	742	-6.9	62	29	752	4.4	47
3,000.....	30	707	3.6	40	30	707	1.5	54	28	702	-4.1	69	30	615	-11.1	65	29	618	-9.9	64	28	606	-8.8	62	29	707	2.1	44
4,000.....	30	624	-3.9	44	30	624	-4.0	52	27	618	-10.8	70	30	539	-17.3	64	29	543	-16.1	61	28	535	-19.7	56	28	624	-3.4	41
5,000.....	30	549	-11.0	42	30	549	-10.2	50	27	542	-16.8	66	30	471	-24.5	63	29	474	-22.9	60	27	467	-26.1	56	28	550	-9.2	39
6,000.....	30	481	-17.7	37	30	481	-16.9	47	27	474	-23.7	62	29	409	-32.6	64	29	413	-30.7	58	27	406	-33.6	54	28	482	-15.7	38
7,000.....	29	420	-25.1	35	30	420	-24.6	44	27	412	-31.4	61	28	355	-40.7	59	29	358	-38.3	57	25	352	-40.9		28	422	-22.4	36
8,000.....	29	365	-33.1	34	30	366	-32.1	44	27	357	-39.4	59	23	306	-48.4		28	308	-46.0		25	302	-48.3		26	318	-38.2	38
9,000.....	29	316	-41.1		30	316	-39.0	42	27	308	-47.3		22	262	-55.5		27	265	-52.7		25	259	-53.9		24	274	-45.8	
10,000.....	29	272	-48.8		30	273	-47.2		27	264	-54.4		21	224	-59.2		26	227	-57.1		24	222	-55.4		25	235	-52.2	
11,000.....	29	233	-54.8		30	234	-53.9		27	226	-59.0		20	190	-58.1		26	194	-57.7		24	190	-55.4		24	201	-57.1	
12,000.....	29	199	-59.4		30	200	-58.8		27	192	-58.4		18	162	-56.4		26	165	-56.3		23	162	-55.2		23	171	-50.3	
13,000.....	29	170	-59.6		30	171	-61.4		27	164	-56.8		17	138	-55.4		23	141	-55.6		20	138	-54.6		22	146	-60.9	
14,000.....	29	144	-59.2		30	145	-61.3		27	140	-55.7		12	118	-55.6		20	121	-56.0		20	118	-54.8		20	124	-62.6	
15,000.....	29	123	-61.0		26	123	-62.6		25	120	-56.1		12	101	-56.8		18	103	-56.7		14	102	-55.8		19	106	-63.9	
16,000.....	28	105	-62.6		26	105	-64.7		24	102	-56.8		10	86	-57.3		16	88	-57.0		10	87	-56.3		18	90	-64.2	
17,000.....	27	89	-62.9		23	89	-65.3		19	87	-57.0		6	75	-57.0		6	75	-56.9		6	74	-56.4		5	76	-63.2	
18,000.....	21	75	-62.6		18	76	-64.3		10	74	-57.2		7	73	-57.0		6	75	-56.9		6	74	-56.4					
19,000.....	11	64	-61.3		11	64	-61.1																					

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																											
	(Patterson Field) Dayton, Ohio (250 m.)				Denver, Colo. (1,616 m.)				El Paso, Tex. (1,193 m.)				Ely, Nev. (1,908 m.)				Fairbanks, Alaska (153 m.)				Joliet, Ill. (178 m.)				Juneau, Alaska (49 m.)			
	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.
Surface.....					30	836	5.6	68	30	880	15.8	27	30	807	4.1	74	29	990	8.3	47	29	994	5.0	77	29	1,010	7.3	69
500.....																	29	950	7.1	46	29	955	6.6	62	29	956	5.4	68
1,000.....																	29	893	3.7	48	29	899	4.6	61	29	899	2.0	70
1,500.....																	29	840	-1.1	51	29	845	2.0	64	29	844	-1.6	72
2,000.....					30	797	6.4	61	30	800	13.3	27	30	798	5.1	67	29	788	-3.6	54	29	794	-4.4	63	29	792	-4.9	72
2,500.....					30	750	3.2	58	30	753	9.7	27	30	751	3.8	60	29	740	-7.0	56	29	746	-2.7	60	29	743	-7.8	70
3,000.....					30	705	1.1	58	30	709	5.9	28	30	706	0.0	61	28	693	-10.4	57	28	700	-4.6	58	29	697	-10.7	69
4,000.....					30	621	-6.5	58	30	626	-1.4	29	30	622	-6.8	61	28	608	-17.3	57	28	615	-10.0	56	29	611	-16.4	64
5,000.....					30	546	-13.4	58	30	552	-8.5	30	29	546	-13.4	59	28	531	-24.1	55	28	540	-15.8	57	29	534	-23.1	65
6,000.....					30	478	-20.0	53	30	484	-16.0	28	29	478	-20.1	57	28	462	-31.4	54	28	472	-22.9	56	26	465	-30.2	60
7,000.....					30	417	-27.5	50	30	423	-23.7	27	29	417	-27.9	54	28	400	-39.2	53	28	410	-30.1	54	25	403	-37.6	60
8,000.....					29	362	-35.4	49	29	368	-35.9	27	29	362	-35.9	53	28	343	-46.6		27	356	-45.1		25	348	-45.1	
9,000.....					29	313	-43.5		29	319	-39.8		29	313	-44.1		28	296	-52.5		27	307	-45.2		23	298	-51.7	
10,000.....					29	268	-51.1		29	275	-47.1		28	269	-51.5		26	253	-55.7		27	264	-52.2		22	255	-55.5	
11,000.....					27	230	-56.2		29	236	-53.7		27	230	-56.9		26	217	-53.5		26	226	-56.9		20	218	-54.9	
12,000.....					27	196	-58.3		29	201	-58.0		27	196	-60.5		24	185	-50.4		26	192	-58.6		18	187	-51.4	
13,000.....					24	168	-57.8		29	172	-58.9		26	167	-60.1		22	159	-48.7		23	164	-57.4		18	160	-49.7	
14,000.....					24	143	-56.5		29	146	-60.1		26	143	-59.1		21	137	-48.0		22	140	-57.0		17	136	-49.3	
15,000.....					22	122	-57.5		26	124	-62.2		23	122	-59.1		20	117	-48.0		20	119	-57.5		14	117	-49.3	
16,000.....					21	104	-58.5		25	106	-60.4		22	104	-60.4		12	101	-48.4		18	102	-58.1		10	100	-49.3	
17,000.....					16	89	-58.9		19	90	-65.9		11	88	-60.9		9	86	-48.5		13	86	-58.5		7	86	-49.1	
18,000.....					10	76	-59.7		10	76	-64.0		13	75	-60.4		7	74	-48.5		8	74	-58.6		5	73	-48.9	

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																											
	Lakehurst, N. J. (39 m.)				Medford, Oreg. (401 m.)				Miami, Fla. (4 m.)				Minneapolis, Minn. (263 m.)				Nashville, Tenn. (180 m.)				Norfolk, Va. (10 m.) <sup>1,2</sup>				Oakland, Calif. (3 m.)			
	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.	Number of ob- ser- va- tions	P.	T.	R. H.
Surface.....	30	1,010	3.8	81	30	970	10.6	72	30	1,017	18.2	87	29	984	5.0	67	30	993	12.3	68	27	1						

TABLE 1.—Mean free-air barometric pressure (P.) in millibars, temperature (T.) in degrees centigrade, and relative humidities (R. H.) in percent, obtained by airplanes and radiosondes during April 1940—Continued

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																											
	Oklahoma City, Okla. (301 m.)				Omaha, Nebr. (301 m.)				Pearl Harbor, T. H. (6 m.) <sup>1 2</sup>				Pensacola, Fla. <sup>1</sup> (24 m.)				Phoenix, Ariz. (339 m.)				St. Louis, Mo. (171 m.)				San Antonio, Tex. (174 m.)			
	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.
Surface	29	967	12.7	67	30	979	8.6	66	30	1,016	21.0	86	27	1,014	16.7	78	30	972	18.6	38	30	994	10.2	70	30	993	17.5	77
500	29	954	13.3	64	30	956	8.3	65	30	960	20.2	77	27	959	15.3	66	30	954	21.3	34	30	955	10.1	64	30	956	17.4	76
1,000	29	899	12.8	56	30	899	7.0	63	30	906	16.9	79	27	904	12.8	64	30	900	19.5	31	30	899	7.7	63	30	902	16.6	66
1,500	29	847	10.1	54	30	846	4.3	64	30	854	14.0	73	27	852	10.6	55	30	848	15.5	31	30	846	5.2	66	30	850	15.1	57
2,000	29	797	8.2	49	29	796	2.2	64	30	805	11.8	66	27	802	9.0	44	30	800	11.4	34	30	796	3.0	66	30	801	13.6	49
2,500	29	750	5.8	47	29	748	—2	62	30	758	10.1	51	27	754	6.6	40	30	753	7.4	38	30	748	—9	63	30	755	11.3	42
3,000	28	705	2.7	46	29	702	—2.6	60	30	714	9.2	34	27	709	4.2	37	30	708	3.9	38	30	702	—1.4	60	30	711	8.5	39
4,000	28	623	—3.9	45	29	618	—8.5	57	30	632	5.8	16	27	627	—1.4	35	30	625	—2.4	39	29	619	—6.9	55	30	629	1.2	36
5,000	28	548	—11.2	45	29	543	—14.9	55	—	—	—	—	26	552	—7.9	39	30	550	—9.4	37	29	544	—13.0	50	30	554	—6.1	35
6,000	28	480	—18.1	42	29	475	—21.9	52	—	—	—	—	26	485	—14.3	41	30	483	—16.8	37	29	476	—19.7	49	29	487	—13.4	35
7,000	28	419	—25.7	39	29	414	—29.6	49	—	—	—	—	26	424	—21.2	42	30	422	—24.8	36	28	415	—27.5	49	29	427	—20.7	35
8,000	28	364	—33.8	38	29	359	—37.5	47	—	—	—	—	25	369	—28.5	43	30	367	—33.2	35	28	360	—35.5	49	28	372	—28.2	35
9,000	27	315	—41.4	—	29	310	—45.0	—	—	—	—	—	25	320	—35.7	48	30	317	—41.0	—	25	312	—43.0	—	28	323	—36.0	35
10,000	26	272	—48.9	—	29	266	—51.7	—	—	—	—	—	21	277	—42.5	—	30	274	—48.4	—	22	268	—50.4	—	28	279	—43.5	—
11,000	26	235	—55.0	—	28	228	—56.9	—	—	—	—	—	20	238	—49.6	—	28	235	—54.6	—	21	229	—57.0	—	27	240	—50.2	—
12,000	26	199	—59.1	—	28	194	—58.9	—	—	—	—	—	18	204	—55.6	—	26	200	—58.3	—	20	195	—62.0	—	25	206	—55.0	—
13,000	26	170	—59.6	—	28	166	—57.7	—	—	—	—	—	14	177	—60.1	—	24	170	—59.4	—	19	166	—59.9	—	25	175	—59.0	—
14,000	25	144	—60.2	—	24	142	—56.9	—	—	—	—	—	11	148	—64.3	—	21	146	—59.8	—	17	141	—58.8	—	24	149	—61.6	—
15,000	24	123	—62.1	—	21	121	—57.5	—	—	—	—	—	10	126	—67.5	—	18	123	—60.7	—	15	120	—59.4	—	24	127	—64.3	—
16,000	19	104	—63.8	—	18	103	—58.7	—	—	—	—	—	7	107	—68.0	—	15	105	—62.3	—	11	102	—60.2	—	22	108	—67.1	—
17,000	18	88	—64.4	—	13	88	—59.3	—	—	—	—	—	7	91	—69.2	—	12	89	—63.1	—	10	86	—60.8	—	20	91	—68.2	—
18,000	14	75	—63.5	—	9	75	—58.8	—	—	—	—	—	5	77	—69.7	—	6	75	—61.8	—	8	73	—59.6	—	15	77	—67.8	—
19,000	7	64	—62.5	—	5	64	—57.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	65	—66.8	—

TABLE 1.—Mean free-air barometric pressure (P.) in millibars, temperature (T.) in degrees centigrade, and relative humidities (R. H.) in percent, obtained by airplanes and radiosondes during April 1940—Continued

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																								
	San Diego, Calif. <sup>1</sup> (19 m.)				Sault Ste. Marie, Mich. (221 m.)				Seattle, Wash. <sup>1</sup> (27 m.)				(Barksdale Field), Shreveport, La. (51 m.)				Spokane, Wash. (506 m.)				Washington, D. C. <sup>1</sup> (7 m.)				
	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	Number of ob- ser- vations	P.	T.	R. H.	
Surface	29	1,013	15.8	76	30	990	0.2	79	24	1,014	11.0	76					30	944	8.6	74	29	1,015	7.2	78	
500	29	958	13.7	73	30	956	—6	75	24	958	9.0	66					30	890	8.1	69	29	955	6.9	62	
1,000	29	903	12.1	65	30	898	—1.6	71	24	902	6.1	65					30	899	4.8	66	29	899	4.8	59	
1,500	29	849	10.1	58	30	843	—4.7	69	24	848	2.7	70					30	846	1.0	66	29	845	2.1	59	
2,000	29	800	8.7	43	30	791	—6.9	67	24	797	—7	78					30	796	—1.6	69	29	794	—5	54	
2,500	29	752	6.2	39	30	742	—8.9	65	24	748	—3.8	76					30	747	—2.6	73	29	746	—1.9	54	
3,000	29	707	2.8	38	30	695	—11.5	63	24	702	—6.4	67					30	702	—6.0	75	29	700	—4.7	55	
4,000	29	624	—2.9	35	30	609	—16.5	60	24	617	—11.6	60					29	617	—12.0	73	29	616	—10.0	58	
5,000	29	549	—9.5	36	30	533	—22.4	58	24	540	—18.0	63					29	541	—18.4	66	29	540	—15.4	54	
6,000	28	482	—16.4	41	30	464	—29.4	57	24	472	—24.3	61					29	472	—25.6	62	29	473	—21.7	50	
7,000	27	422	—24.1	45	30	402	—36.4	53	24	411	—31.9	66					29	410	—23.2	63	29	412	—29.2	53	
8,000	27	367	—31.7	49	30	348	—43.2	—	21	356	—39.5	68					29	355	—40.6	61	25	358	—36.4	—	
9,000	27	317	—39.2	—	30	299	—49.3	—	20	307	—46.8	—					29	306	—47.8	—	22	308	—43.8	—	
10,000	27	274	—47.0	—	30	257	—54.2	—	20	264	—52.6	—					28	262	—53.5	—	19	265	—50.9	—	
11,000	26	235	—54.1	—	28	220	—56.1	—	18	226	—56.1	—					28	225	—56.0	—	15	227	—57.3	—	
12,000	25	200	—58.4	—	28	188	—55.7	—	15	193	—56.5	—					28	192	—55.7	—	9	193	—61.5	—	
13,000	25	171	—59.5	—	28	160	—54.9	—	14	165	—55.6	—					27	164	—54.4	—	6	165	—61.5	—	
14,000	21	146	—60.0	—	27	137	—54.9	—	13	141	—54.4	—					26	140	—54.0	—	5	140	—60.7	—	
15,000	20	124	—61.2	—	23	116	—55.2	—	12	121	—53.3	—					23	120	—54.3	—	—	—	—	—	—
16,000	15	106	—62.2	—	16	99	—55.8	—	8	103	—53.1	—					20	103	—54.7	—	—	—	—	—	—
17,000	13	90	—62.6	—	10	85	—56.2	—	—	—	—	—					12	89	—55.3	—	—	—	—	—	—
18,000	10	77	—62.0	—	6	72	—55.8	—	—	—	—	—					—	—	—	—	—	—	—	—	—
19,000	7	65	—61.0	—	—	—	—	—	—	—	—	—					—	—	—	—	—	—	—	—	—

<sup>1</sup> U. S. Navy.<sup>2</sup> Airplane observations.

NOTE.—All observations taken at 1 a. m., 75th meridian time, except those at Washington, D. C., Lakehurst, N. J., Norfolk, Va., and Pensacola, Fla., where they are taken before 5 a. m., 75th meridian time. At Pearl Harbor, T. H., observations are taken after sunrise.

None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

Number of observations refers to pressure only as temperature and humidity data are missing for some observations at certain levels; also, the humidity data are not used in daily observations when the temperature is below  $-40.0^{\circ}\text{C}$ .

TABLE 2.—Free-air resultant winds based on pilot-balloon observations made near 5 p. m. (75th meridian time) during April 1490

[Directions given in degrees from North (N=360°, E=90°, S=180°, W=270°)—Velocities in meters per second]

Altitude (meters) m. s. l.	Abilene, Tex. (537 m.)			Albuquerque, N. Mex. (1,630 m.)			Atlanta, Ga. (299 m.)			Billings, Mont. (1,095 m.)			Bismarck, N. Dak. (512 m.)			Boise, Idaho (870 m.)			Brownsville, Tex. (7 m.)			Buffalo, N. Y. (220 m.)			Burlington, Vt. (132 m.)			Charleston, S. C. (18 m.)			Chicago, Ill. (192 m.)			Cincinnati, Ohio (187 m.)			Denver, Colo. (1,627 m.)		
	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity			
Surface.....	30	309	2.1	30	263	3.8	29	241	2.7	27	2	1.4	26	9	1.4	28	326	3.8	29	125	4.5	29	322	1.9	28	300	0.9	30	212	2.2	28	17	1.5	27	277	0.9	28	7	0.6
500.....	29	240	2.5	28	241	3.2	28	245	3.3	27	320	1.7	23	322	1.1	28	323	4.0	24	197	1.8	29	294	2.5	28	268	1.8	30	221	4.4	28	20	2.1	27	230	1.1	28	230	1.1
1,000.....	28	241	3.2	30	265	3.7	24	264	7.9	22	298	3.2	20	333	2.3	27	308	4.8	19	286	4.3	21	284	6.7	17	288	6.1	25	268	8.2	21	277	3.0	19	255	7.3	28	345	0.8
1,500.....	26	248	5.5	28	261	4.5	19	282	9.1	19	285	6.7	16	309	2.8	25	286	4.4	18	277	5.0	18	292	8.6	12	301	7.7	21	276	8.9	18	283	3.9	16	273	9.0	27	300	3.4
2,000.....	24	261	7.0	27	266	4.6	17	286	11.4	18	287	7.9	14	311	5.9	23	275	5.8	18	272	6.4	15	300	9.8	10	300	7.6	18	280	9.9	17	295	6.0	14	287	11.5	23	283	7.7
2,500.....	22	268	9.0	27	266	4.5	17	286	11.4	18	287	7.9	14	311	5.9	23	275	5.8	18	272	6.4	15	300	9.8	10	300	7.6	18	280	9.9	17	295	6.0	14	287	11.5	23	283	7.7
3,000.....	21	274	12.1	24	276	8.9	16	287	15.4	13	287	10.2	11	323	8.9	16	276	8.3	14	273	10.8	10	284	13.8	10	284	13.8	10	284	13.8	10	284	13.8	10	284	13.8	10	284	13.8
4,000.....	20	279	15.6	20	276	13.0	15	290	18.3	10	304	12.0	11	323	8.9	16	276	8.3	14	273	10.8	10	284	13.8	10	284	13.8	10	284	13.8	10	284	13.8	10	284	13.8	10	284	13.8
5,000.....	18	279	21.1	16	284	16.4	13	283	19.4	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9
6,000.....	13	284	21.6	11	289	18.0	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9
8,000.....	13	284	21.6	10	290	18.7	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9
10,000.....	13	284	21.6	10	290	18.7	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9	10	284	23.9

Altitude (meters) m. s. l.	El Paso, Tex. (1,196 m.)			Ely, Nev. (1,910 m.)			Grand Junction, Colo. (1,413 m.)			Greensboro, N. C. (271 m.)			Havre, Mont. (766 m.)			Jacksonville, Fla. (14 m.)			Las Vegas, Nev. (570 m.)			Little Rock, Ark. (79 m.)			Medford, Oreg. (410 m.)			Miami, Fla. (10 m.)			Minneapolis, Minn. (361 m.)			Mobile, Ala. (10 m.)			Nashville, Tenn. (194 m.)		
	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity			
Surface.....	30	257	4.0	28	284	1.4	29	303	1.8	27	255	2.3	22	7	0.9	29	151	1.3	30	206	1.9	29	166	1.0	28	316	1.9	30	126	2.5	27	19	0.7	27	187	2.3	29	228	2.6
500.....	29	240	2.5	28	241	3.2	28	245	3.3	27	242	4.0	22	27	1.0	29	219	1.9	30	217	1.7	27	211	5.1	28	315	2.4	30	127	2.5	27	77	1.1	27	202	3.9	29	223	3.3
1,000.....	30	261	4.8	28	261	4.5	29	261	4.5	27	241	5.0	22	27	1.0	29	219	1.9	30	217	1.7	27	211	5.1	28	315	2.4	30	127	2.5	27	77	1.1	27	202	3.9	29	223	3.3
1,500.....	30	263	5.8	28	261	4.5	29	261	4.5	27	241	5.0	22	27	1.0	29	219	1.9	30	217	1.7	27	211	5.1	28	315	2.4	30	127	2.5	27	77	1.1	27	202	3.9	29	223	3.3
2,000.....	30	263	5.8	28	261	4.5	29	261	4.5	27	241	5.0	22	27	1.0	29	219	1.9	30	217	1.7	27	211	5.1	28	315	2.4	30	127	2.5	27	77	1.1	27	202	3.9	29	223	3.3
2,500.....	29	264	7.5	28	276	2.2	29	266	3.5	19	278	9.1	18	278	7.6	22	279	7.7	30	245	2.6	25	249	7.7	27	243	2.6	27	280	4.1	23	254	2.8	17	300	6.8	25	241	6.2
3,000.....	28	260	8.4	26	269	3.4	27	261	4.1	13	293	8.5	13	289	6.8	21	284	8.8	30	259	3.6	17	278	10.9	23	252	4.7	26	276	5.3	18	241	4.3	16	297	10.1	17	277	9.0
4,000.....	24	270	9.4	22	275	5.6	21	267	5.2	11	298	13.5	10	295	9.0	19	289	12.3	28	270	4.8	14	294	15.7	21	273	7.4	25	282	8.9	12	291	13.4	10	300	13.5	10	300	13.5
5,000.....	17	274	11.6	17	282	8.4	19	292	8.7	11	298	13.5	10	295	9.0	16	283	15.4	25	278	8.0	14	294	15.7	21	273	7.4	25	282	8.9	12	291	13.4	10	300	13.5	10	300	13.5
6,000.....	15	269	12.5	14	295	11.1	13	295	10.6	11	298	13.5	10	295	9.0	15	279	17.4	24	274	10.5	14	294	15.7	21	273	7.4	25	282	8.9	12	291	13.4	10	300	13.5	10	300	13.5
8,000.....	15	269	12.5	14	295	11.1	13	295	10.6	11	298	13.5	10	295	9.0	15	279	17.4	24	274	10.5	14	294	15.7	21	273	7.4	25	282	8.9	12	291	13.4	10	300	13.5	10	300	13.5
10,000.....	15	269	12.5	14	295	11.1	13	295	10.6	11	298	13.5	10	295	9.0	15	279	17.4	24	274	10.5	14	294	15.7	21	273	7.4	25	282	8.9	12	291	13.4	10	300	13.5	10	300	13.5
12,000.....	15	269	12.5	14	295	11.1	13	295	10.6	11	298	13.5	10	295	9.0	15	279	17.4	24	274	10.5	14	294	15.7	21	273	7.4	25	282	8.9	12	291	13.4	10	300	13.5	10	300	13.5
14,000.....	15	269	12.5	14	295	11.1	13	295	10.6	11	298	13.5	10	295	9.0	15	279	17.4	24	274	10.5	14	294	15.7	21	273	7.4	25	282	8.9	12	291	13.4	10	300	13.5	10	300	13.5

Altitude (meters) m. s. l.	New York, N. Y. (15 m.)			Oakland, Calif. (8 m.)			Oklahoma City, Okla. (402 m.)			Omaha, Nebr. (306 m.)			Phoenix, Ariz. (344 m.)			Rapid City, S. Dak. (982 m.)			St. Louis, Mo. (181 m.)			San Antonio, Tex. (183 m.)			San Diego, Calif. (15 m.)			Sault Ste. Marie, Mich. (230 m.)			Seattle, Wash. (14 m.)			Spokane, Wash. (603 m.)			Washington, D. C. (10 m.)		
	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity	Observations	Direction	Velocity			
Surface.....	27	288	2.7	30	257	4.8	29	96	1.3	28	340	1.2	30	252	2.6	27	345	4.0	26	107	0.7	30	105	1.3	28	264	4.2	29	311	4.5	26	258	1.8	29	231	3.0	26	293	7.8
500.....	27	281	3.9	30	284	4.0	29	102	1.4	28	360	1.2	30	256	3.0	27	342	4.1	26	33	0.7	30	108	1.7	28	273	3.5	29	311	5.3	26	229	1.3	29	230	3.3	24	271	4.5
1,000.....	24	289	5.7	29	298	3.3	28	107	0.5	26	86	0.6	30	253	3.4	27	342	4.1	25	264	0.6	29	182	1.6	28	267	2.0	27	306	4.7	25	215	2.8	29	230	3.3	24	271	4.5
1,500.....	23	284	8.0	27	308	3.4	28	243	1.8	24	264	1.6	30	246	3.1	27	329	4.7	22	245	2.3	26	255	3.1	25	269	1.1	27	328	3.9	23	237	3.9	28	239	4.2	22	278	9.6
2,000.....	15	297	8.6	26																																			

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TABLE 4.—Mean altitudes and temperatures of significant points identifiable as tropopause during March 1940, etc.—Continued

Potential temperatures, °A.	Medford, Oreg.			Miami, Fla.			Minneapolis, Minn.			Nashville, Tenn.			Oakland, Calif.			Oklahoma City, Okla.			Omaha, Nebr.		
	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.
290-299	4	8.0	49.0				2	7.2	49.5				4	7.4	40.2				1	7.3	46.0
300-309	7	9.5	55.9				2	7.8	44.5										2	8.0	46.5
310-319	17	10.8	59.4	1	10.3	48.0	11	9.0	40.7	3	8.9	47.3	6	8.6	45.8	3	7.9	38.0	9	9.0	40.1
320-329	16	11.8	61.8	11	11.1	50.6	18	10.4	57.1	9	10.7	56.1	24	10.6	55.5	12	10.4	54.6	20	10.7	57.4
330-339	5	12.6	65.6	18	12.5	58.2	15	11.6	61.4	18	11.8	60.5	17	12.2	64.8	19	11.7	60.6	20	11.6	60.6
340-349				11	13.7	64.2	4	12.8	64.5	7	12.7	64.6	8	13.1	67.6	6	12.6	63.8	4	12.2	60.0
350-359				10	14.6	67.6	2	12.6	57.5	6	12.9	60.5	1	12.8	54.0	2	14.0	68.5	3	12.4	56.0
360-369	1	13.4	57.0	2	15.8	72.5				1	14.5	69.0				1	13.1	55.0	1	12.7	55.0
370-379	2	14.4	57.5	7	16.3	73.0	1	14.1	54.0	2	14.2	60.0	3	14.9	61.0	1	15.6	68.0			
380-389	2	15.1	59.5	6	17.1	75.3				4	15.6	63.5	1	15.3	62.0	5	16.1	67.0	1	13.6	52.0
390-399	1	16.0	63.0	7	17.5	74.0				2	16.4	65.5	8	15.9	62.0	3	16.3	65.3	2	14.8	58.5
400-409																			3	15.4	58.3
Weighted means		11.3	59.4		14.0	63.8		10.6	56.6		12.3	60.1		11.8	58.7		12.2	59.4		11.2	56.8
Mean potential temperature °A (weighted)	332.9			361.8			326.7			344.6			339.8			341.5			335.0		
Number days with observations	27			28			26			28			28			25			28		

Potential temperatures, °A.	Phoenix, Ariz.			St. Louis, Mo.			San Antonio, Tex.			San Diego, Calif.			Sault Ste Marie, Mich.			Seattle, Wash.			Spokane, Wash.		
	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.
290-299													2	6.9	48.0						
300-309	1	8.2	47.0							1	7.1	36.0	17	7.6	45.2	2	7.6	43.0	4	8.1	47.2
310-319	4	8.1	41.2	5	8.5	42.2				2	8.0	42.0	14	9.4	54.9	4	9.6	56.8	15	9.5	54.5
320-329	16	10.8	56.8	15	10.7	56.3	8	9.9	45.4	11	10.3	52.3	17	10.5	58.1	7	10.5	58.4	22	10.5	57.5
330-339	13	11.6	59.2	14	11.8	61.5	14	11.0	52.6	14	11.7	60.6	9	11.5	61.2	3	11.6	61.3	9	11.1	57.1
340-349	10	12.8	63.5	8	12.4	62.0	13	12.3	56.8	7	12.8	63.7	1	11.2	54.0	4	12.2	61.2	5	12.2	62.0
350-359	2	12.7	58.5	2	13.5	66.0	9	13.2	60.0	1	11.5	50.0	2	13.0	60.5				2	11.7	51.5
360-369	1	13.1	54.0				6	14.1	62.0				1	12.0	51.1						
370-379	2	14.2	61.5	2	13.4	57.5	2	14.6	63.0				1	13.0	53.0						
380-389							8	15.9	68.4	3	14.8	61.0	2	13.6	54.0						
390-399	1	14.8	54.0	2	14.8	56.5	2	15.7	63.0	3	16.1	66.0	1	14.5	56.0				1	15.1	58.0
400-409	3	16.6	68.7				5	16.7	67.6	2	16.4	63.5	3	14.6	54.3				1	15.6	59.0
Weighted means		11.8	58.1		11.5	57.8		12.9	58.0		12.0	57.9		10.1	53.9		10.6	57.6		10.5	56.2
Mean potential temperature °A (weighted)	339.0			335.7			354.7			342.7			326.2			326.0			327.0		
Number days with observations	27			19			26			24			30			16			27		

Potential temperatures, °A.	Washington, D. C.			Atlantic Sta. 1, approx. lat. 36, long. 53			Atlantic Sta. 2, approx. lat. 42, long. 38		
	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m. s. l.	Mean temperature °C.
300-309	1	7.9	48.0	2	7.5	41.0	2	7.4	39.0
310-319	5	8.9	48.2	5	8.5	44.2	3	9.0	49.3
320-329	6	10.3	54.8	17	10.8	58.8	10	10.5	58.2
330-339	7	11.5	59.9	11	11.6	58.9	10	12.1	62.5
340-349	1	13.6	68.0	7	12.3	60.4	7	13.2	68.4
350-359				2	13.6	65.0	4	13.6	66.2
360-369							2	13.8	61.0
370-379				2	14.5	62.5			
380-389				3	14.3	57.7	1	14.0	56.0
390-399							1	14.6	56.0
400-409				2	15.6	57.0	1	16.3	64.0
Weighted means		10.4	55.2		11.5	57.2		11.9	59.9
Mean potential temperature °A (weighted)	326.0			337.9			338.4		
Number days with observations	15			25			23		

## RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in Charge]

By BENNETT SWENSON

**Atlantic slope drainage.**—The principal flooding during this month in this region was that in the Susquehanna River, mention of which was made in the previous issue of the REVIEW. A complete report will be made in a later issue.

Minor rises, approaching or slightly exceeding flood stage, occurred principally in the Merrimack, Connecticut, Delaware, Potomac, James, Neuse, and Roanoke Rivers. The floods were slight or moderate and no damage of consequence was reported. Rather general flooding occurred in New York State in the smaller streams from moderate to heavy rains the latter part of March which caused the melting of a moderately heavy snow cover.

The following report is submitted by the official in charge, Concord, N. H., relative to the rise in the Merrimack River Basin:

Ice in the river began to break up on March 30, and had entirely disappeared by the end of the first week in April. Stages began to rise above the normal winter low on April 2, reaching and slightly passing flood stages on the 13th and 14th, in the central section of the Merrimack Basin.

A sharp increase occurred in stages on the main river from Franklin to Lawrence on April 12 due to an average  $1\frac{1}{2}$  inch rainfall in that reach of the river. A considerable rise occurred in the Contoocook River, where a large amount of snow melted. However, in the area of heavy accumulated snow (the Pemigewasset River) the amount of run-off was negligible, due to continued moderately low temperatures.

As the river was quite swollen before the rain of April 12 began, and as the amount that fell was considerable, a serious freshet would have occurred, except for the fact that a sharp freeze followed the storm. The rapid retardation of the run-off after the passage of the cold front was phenomenal.

Considerable valley storage below Manchester, combined with the fact that there was practically no snow in the lower tributaries, prevented the Merrimack from reaching flood stages in the lower reaches.

**East Gulf of Mexico drainage.**—The Apalachicola River reached flood stage at Blountstown, Fla., on April 8 and remained above that stage until the 12th, but no appreciable damage occurred.

Moderate flooding prevailed in portions of the Black Warrior and Tombigbee Rivers during most of the month from frequent heavy rains. Damage was slight except in the Tombigbee north of Aberdeen, Miss., where 90,000 acres of land were inundated with a loss estimated at \$700,000, mostly to prospective crops.

Above flood stages were registered in the Pearl River at Jackson, Miss., and Pearl River, La., with only slight losses due to suspension of business.

## MISSISSIPPI SYSTEM

**Upper Mississippi Basin.**—The following is reported by the Official in Charge, La Crosse, Wis., relative to a rise in the Chippewa River and the Mississippi in the vicinity of La Crosse:

Cautionary warnings were issued on April 11 for a 10-foot stage (flood stage 11 feet) at Durand, Wis., for the 13th. A hard freeze with temperatures ranging from  $12^{\circ}$  to  $15^{\circ}$  above in northern Wisconsin occurred on the 12th resulting in an abrupt checking of surface run-off from melting snow. Crest at Durand did not exceed 7.5 feet for this reason.

Crest stages from melting snow this month in the Mississippi River closely agreed with the results of the snow survey made the latter part of February. The date of the crest of high water in the lower section of the district was forecast the first of April to occur between the 15th and 18th. The actual crest of 7.8 feet occurred at La Crosse on the 18th. This is the lowest crest stage with surface run-off from melting snow since the Spring of 1931.

As was stated in the snow survey, the unusually dry condition in the fall of 1939 was responsible for a high percentage of initial loss into the soil, and together with periods of unseasonably cold weather held in check any extensive surface run-off.

**Missouri Basin.**—Heavy rains in eastern South Dakota, southwestern Minnesota, and western Iowa, caused high water in the Big Sioux River from April 1 to 8, at Akron, Iowa, and a day later near Sioux City, Iowa. Overflow was confined to low ground along the river and no damage of consequence occurred.

Flooded creeks in the vicinity of Chinook, Mont., on April 20, inundated several hundred acres of farm land and caused property damage estimated at \$2,700.

**Ohio Basin.**—Flooding occurred quite generally in the Ohio Basin, extending from the latter part of March in the upper portion, to May in the lower portion. A complete report will be included in the next issue of the REVIEW.

**White Basin.**—Heavy rains on April 12 and 13 resulted in flood stages on the Black and White Rivers in Missouri and Arkansas. The flooding continued into May in the lower portions. The greatest damage reported was in the upper White with a loss to prospective crops amounting to \$10,000.

**Red Basin.**—Slight flooding occurred in the Sulphur River at Ringo Crossing and Naples, Tex., from April 6 to 18. No damage of consequence was reported.

**Lower Mississippi Basin.**—The report from the Memphis river district office relative to floods in the St. Francis River follows:

As a result of a heavy rainfall in the headwaters of the St. Francis River, on April 11, warnings were issued for flood stages at Fisk, Mo., and St. Francis, Ark. Owing to additional moderately heavy rainfall on the 18th, and on the 19th in the upper basin, warnings were revised.

At Fisk, Mo., the river crested at 23.0 feet on April 14 and, after a fall of a few days, again crested at 23.4 feet on April 22, although the 24-hour rise on the 22d was only 0.1 foot. The heavy rainfall that occurred on the 18th and 19th gave a stage of 19.9 feet at St. Francis, on the 19th. The river continued to rise at St. Francis, with the exception of no change on the 21st, and crested at a stage of 20.9 feet on the 25th.

The Mississippi rose quite rapidly in the early part of the month and on April 10th a crest stage of 22.4 feet was reached on the 13th at Memphis, Tenn.

Another rise started at Memphis on the 20th, which reached 29.9 feet at the end of the month and was still rising.

**West Gulf of Mexico drainage.**—Moderate overflows occurred from the Trinity River at Trinidad, Tex., from April 10 to 16, with a crest stage of 31.0 feet on the 12th. No appreciable loss was reported but, due to timely warnings, it has been estimated that movable property and livestock valued at \$15,000 were saved.

**Pacific slope drainage.**—A second major flood occurred in the Sacramento River within a month's time from the first. The Sacramento, Calif., office reports as follows:

## FLOODS IN THE SACRAMENTO AND SAN JOAQUIN VALLEYS MARCH 29-APRIL 6, 1940

E. H. FLETCHER

[Weather Bureau, Sacramento, Calif., June 1940]

Following the major flood in the Sacramento Valley at the beginning of March, there was a period of about three weeks when no appreciable precipitation occurred, although the same general tendency for low-pressure areas to move far southward in the ocean persisted.

An occluded front, in connection with an extensive field of low pressure off the north Pacific coast, reached the coast line of Wash-

ington, Oregon, and northern California on March 24, preceded by an upper cold front. Frontal activity increased in frequency and intensity during the week that followed. The situation was somewhat similar to that which preceded the flood earlier in March.<sup>1</sup>

The first general intensive rainfall occurred on March 27, and the resultant run-off filled the depleted river channels; the heavier rainfall that continued during the next 4 days was an easy step to another major flood.

In contrast to the early March flood of this year, the streams during the present flood were not so extremely high in the upper Sacramento area, but much higher water prevailed this time on the Yuba, Bear, American, Cosumnes, Mokelumne, and lower San Joaquin Rivers. However, no new high water records were established, except at Bensons Ferry on the lower Mokelumne River, where a crest stage of 15.5 feet was reached on April 1. The previous high record there was 15.4 feet in February 1938.

The first general warnings for the upper Sacramento Valley area were published as early as March 28, and on the following day warnings of stages substantially above the flood or danger stages were issued to all concerned and given the widest possible distribution. Additional warnings were issued on the 30th and 31st to points farther down the stream, including the Feather and American Rivers, and the tributaries of the lower San Joaquin.

The rapid rise in the river at Sacramento on the 29th by reason of the heavy discharge from the American River, occasioned the opening of 18 gates of the Sacramento Weir at 11 a. m., after which the water level fell slightly at Sacramento. But the increasing flow from the American and Yuba-Bear Rivers, required the opening of more gates during the next 24 hours in order to maintain a river level below the danger stage. A total of 42 gates out of a possible of 48 was opened.

Excessive rainfall was centered in the Sacramento River canyon, where Kennett reported 7.92 inches on March 30. The greatest 24-hour rainfall occurred at Brush Creek on the Middle Fork of the Feather River, where 9.16 inches were measured on the same day. The drainage from local creeks in the upper Sacramento Valley was comparatively light, otherwise much higher water would have resulted in Tehama County.

The previous breaks in the levees on Sutter Bypass east of Meridian had not been repaired, and as a result Reclamation Districts Nos. 70 and 1660, which had continued to be partially covered with water since early in March, were reflooded. Likewise, overflow water from the old breaks along both sides of the river in the vicinity of Butte City reflooded some of the area in the Butte Basin on the east side, and the Colusa Trough area on the west side of the river. However, the affected area was not so extensive as it was in the earlier flood.

As much of the original damage had not yet been repaired and farming operations had not been resumed in the overflow areas since the first inundation, the extent of additional damage was comparatively light. The reflooding of about the same island tracts in the Delta region also occurred.

On March 30 an old levee break on the lower San Joaquin River permitted the flooding, for the second time this month, of about 2,500 acres of land on the River Junction Farms near the confluence of the Stanislaus and San Joaquin Rivers.

Generally speaking, the flood under discussion may be considered as a duplication on a smaller scale of the conditions that occurred at the beginning of the month of March.

During the critical period, the radio station KFBK in Sacramento broadcast hourly bulletins throughout the day and night regarding the high-water situation in general, sending out warnings and transmitting authentic information, which was obtained from the Weather Bureau, the United States Engineer Office, the Works Progress Administration, the State Division of Highways, and the State Division of Water Resources. The State Department of Public Works acted as the clearing house for the information.

This broadcast constituted a valuable service whereby the entire valley was kept constantly and reliably informed as to the progress of every phase of the flood as affecting every activity. The field engineers of the United States and State reported the conditions of levees, and indicated where breaks were occurring and just what areas would be endangered by overflow waters, including the infor-

mation as to the closing of highways, and the blocking of railroads, and other pertinent information.

Following is a tabulation of the daily precipitation for the storm period at the principal rainfall stations in the elevated regions; and a table showing the crest stages for the valley river stations during the high-water period.

Rainfall from Mar. 24 to Mar. 31, 1940, inclusive (inches)

Stations	Elevation (feet)	24	25	26	27	28	29	30	31	Total
<b>Sacramento River</b>										
Mineral	4,950	0.06	0.03	2.05	.02	0.36	1.80	3.01	0.0	7.42
Mt. Shasta	3,555	.21	.06	1.01	.08	.26	1.49	2.05	.35	5.50
McCloud	3,270	.37	1.12	1.12	.36	1.40	2.09	1.99	.07	8.52
Hobergs	2,980	0	.05	1.31	2.36	.62	.68	2.23	1.00	7.25
Kilare P. H.	2,642	.54	.62	1.15	.25	.67	1.21	.98	.99	6.41
Dunsmuir	2,300	.45	.51	1.75	1.00	1.01	2.93	1.88	1.42	11.01
Montgomery Creek	2,145	.93	.77	1.09	.50	1.76	.92	1.87	.22	8.06
Volta P. H.	2,100	.86	.36	.85	.36	.59	.57	.58	.90	4.87
Clear Lake	1,350	.03	0	1.02	.11	.29	.40	1.09	.10	3.04
Volmers	1,332	.10	.60	2.39	.02	1.40	3.55	2.87	.27	11.29
Beegum	1,291	.01	.07	1.25	.86	.42	.92	.72	.15	4.40
Stonyford	1,205	0	0	.62	1.10	.38	.62	.51	.08	2.71
Middletown	1,105	0	.05	.61	2.70	.40	1.00	3.06	.89	8.71
Squaw Creek	900	0	1.74	1.40	2.28	.60	4.25	4.06	2.37	16.70
Stony Gorge Reservoir	800	.05	T	.52	0	.39	.40	.24	.09	1.69
Paskenta	740	0	0	.35	.52	.25	.52	.29	.44	2.37
Redding	718	.42	.34	1.33	.03	2.36	1.93	2.57	T	8.98
Kennett	655	.02	1.16	2.12	2.62	.42	3.05	7.92	2.91	20.22
Sacramento	25	.22	.12	1.10	T	.21	.96	1.60	0	4.21
<b>Feather River</b>										
Bucks Storage Reservoir	5,070	.46	.50	3.66	2.16	1.08	6.40	4.20	.70	19.16
Canyon Dam	4,570	.33	.14	1.79	.46	.86	2.43	3.13	.50	9.34
Stirling City	3,525	0	0	2.61	3.26	.72	2.60	5.75	2.67	17.61
Brush Creek	3,500	0	.98	1.75	3.91	.80	2.51	9.16	2.91	22.02
Quincy	3,409	0	.41	2.10	1.05	.31	2.67	3.36	1.10	11.09
West Branch	3,216	0	2.17	2.78	.57	.94	4.06	5.10	1.32	16.94
Feather Falls	2,973	0	2.92	2.08	.76	1.49	5.01	1.86	.....	.....
De Saba	2,700	.92	.12	3.14	.12	1.05	3.64	5.74	1.70	16.43
Challenge	2,700	.80	1.71	2.20	1.60	1.20	4.17	7.05	.92	19.65
Bucks Creek	1,750	.57	.29	2.60	1.95	.75	2.76	4.23	1.46	14.61
Las Plumas	569	.62	0	3.08	1.36	1.18	3.35	5.11	.69	15.39
Oroville	273	0	.68	1.25	.58	.37	.62	2.32	.70	6.52
<b>Yuba-Bear River</b>										
Bowman Dam	5,347	.23	.80	3.98	1.84	.91	2.81	4.40	1.66	16.63
Lake Spaulding	5,070	.33	.52	4.11	1.66	1.08	3.24	4.40	1.30	16.64
Scales	4,300	.63	.42	4.60	1.50	1.22	4.45	5.37	1.39	19.61
Deer Creek	3,700	.48	.34	3.38	2.21	1.00	3.24	5.39	1.72	17.76
N. Bloomfield	3,100	0	.70	.77	2.45	.80	1.12	4.76	2.70	13.00
Downsville	2,890	0	.65	.64	4.44	1.08	1.91	5.84	2.83	17.39
Camptonville	2,850	.76	.26	4.93	4.64	1.02	4.30	3.16	.11	15.18
Nevada City	2,570	0	.58	.68	2.46	.54	1.07	4.31	2.30	11.94
Chute Camp	1,358	.35	.05	3.74	2.25	1.02	3.26	4.35	.94	15.96
Colgate	582	.92	1.44	2.35	.48	.98	3.72	1.56	.20	11.65
<b>American River</b>										
Twin Lakes	7,920	0	.56	.90	3.20	.45	2.14	2.90	.60	10.75
Soda Springs	6,752	0	.64	.74	3.28	.58	1.22	3.11	2.04	11.61
Blue Canyon	4,750	0	.86	1.30	3.74	.82	1.55	3.73	2.90	14.90
Riverton	3,230	0	.93	.66	2.91	.61	.43	2.34	3.04	10.92
Gold Run	3,227	0	.84	.43	3.43	.30	.98	3.78	2.87	12.63
Iowa Hill	2,970	0	.72	.54	2.86	.42	.82	3.47	2.65	11.48
Colfax	2,421	.60	.24	2.86	.20	.75	3.53	2.69	0	10.87
Georgetown	2,300	.69	.07	3.86	.26	.64	2.83	3.38	.15	11.38
Foresthill	2,200	0	.72	.83	3.35	.33	.55	2.91	2.86	11.55
Placerville	1,925	.62	0	1.65	1.12	.40	1.32	2.52	1.23	8.86
El Dorado P. H.	1,887	.29	.60	2.22	1.51	.57	2.20	4.23	2.22	13.84
Folsom	252	0	.45	.71	1.06	.21	.14	1.50	.97	5.04
<b>Cosumnes River</b>										
Fiddletown	2,100	.50	.10	3.20	.05	.24	1.62	2.72	.21	8.64
Big Canyon Mine	850	.10	0	.73	0	1.25	1.50	.70	1.35	5.63
<b>Calaveras River</b>										
San Andreas	996	0	.74	.65	1.32	.25	.13	.54	2.45	6.08
<b>Mokelumne River</b>										
Hetch Hetchy	3,530	0	.40	.34	3.26	.16	.41	.43	1.81	6.81
Sonoma	1,825	T	.66	1.08	1.28	.25	.47	1.49	1.42	6.65

<sup>1</sup> Floods in the Sacramento Valley, February 27-March 6, 1940. E. H. Fletcher, M. W. R. Vol. 68, pp. 71-74.

## High water, March-April 1940

	Crest stage (feet)	Time and date	Departure from flood stage (feet)
<b>Sacramento River</b>			
Kennett	23.1	7 p. m., Mar. 30	-1.9
Red Bluff	28.0	3 a. m., Mar. 31	+5.0
Hamilton City	20.8	3 p. m., Mar. 31	+1.8
Ord Ferry	119.1	11 p. m., Mar. 31	-1.8
Colusa	26.2	Noon, Apr. 1	+1.6
Knights Landing	31.6	4 a. m., Apr. 1	-1.6
Sacramento	28.46	10:45 p. m., Mar. 30	-1.5
<b>Feather River</b>			
Oroville	24.1	Noon, Mar. 30	-0.9
Nicolaus	25.6	Noon, Mar. 31	+0.6
<b>Yuba River</b>			
Colgate	15.3	11 a. m., Mar. 30	-2.5
Marysville	25.5	7 a. m., Mar. 31	-2.5
<b>American River</b>			
Folsom	21.9	10 p. m., Mar. 30	-1.6
H St. Bridge	41.6	4 a. m., Mar. 31	+1.6
<b>Stony Creek</b>			
St. John	5.4	—, Mar. 31	-6.6
<b>Mokelumne River</b>			
Bensons Ferry	15.5	2 p. m., Apr. 1	+3.5
<b>San Joaquin River</b>			
Lathrop	16.6	8 p. m., Apr. 2	-4

Estimated flood losses during April <sup>1</sup>

River and drainage	Tangible property	Matured crops	Prospective crops	Live-stock and other movable farm property	Suspension of business	Total
<b>East Gulf of Mexico</b>						
Tombigbee River			\$700,000			\$700,000
Pearl River					\$4,000	4,000
<b>Mississippi system</b>						
Rivers in Montana	\$2,700					2,700
Black River in Arkansas			1,000			1,000
White River in Arkansas			10,500			10,500
<b>West Gulf of Mexico</b>						
Trinity River			1,250			1,250
<b>Pacific slope</b>						
Sacramento River	329,128	\$83,000	206,800	\$70,000	70,530	750,458

<sup>1</sup> Losses resulting from floods in the Susquehanna and Ohio River Basins not included.  
<sup>2</sup> Mostly to prospective crops.

## Flood-stage report for the month of April 1940

River and station	Flood stage	Above flood stages— dates		Crest	
		From—	To—	Stage	Date
ST. LAWRENCE DRAINAGE					
Lake Erie					
St. Marys: Decatur, Ind.....	Feet 13	19	25	Feet 17.3	22
ATLANTIC SLOPE DRAINAGE					
Contoocook: Penacook, N. H.....	7	13	14	7.2	14
Merrimack: Concord, N. H.....	12	13	14	13.1	14
Connecticut:					
Montague City, Mass.....	28	13	14	30.1	13
Holyoke, Mass.....	9	13	14	9.15	14
Hartford, Conn.....	16	9	17	21.4	14
		19	24	20.0	22
Delaware:					
Easton, Pa.....	22	(1)	1	26.2	1
Trenton, N. J.....	12	(1)	2	12.9	1
Potomac: Washington, D. C. (near).....	10	21	23	11.2	21-22
James:					
State Farm, Va.....	12	9	9	12.0	9
		22	22	13.0	22
		8	12	16.2	9
Columbia, Va.....	10	21	24	18.0	22

## Flood-stage report for the month of April 1940—Continued

River and station	Flood stage	Above flood stages— dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE—continued					
Roanoke:	<i>Feet</i>			<i>Feet</i>	
Randolph, Va.	21	10	10	21.1	10
Weldon, N. C.	31	11	11	31.0	11
Williamston, N. C.	10	16	17	10.1	16
		25	29	10.1	27-28
Neuse:					
Neuse, N. C.	15	21	22	15.3	21
Smithfield, N. C.	13	21	24	16.6	
					22
Savannah: Clio, Ga.	11	( <sup>1</sup> ) 22	5	15.0	
			28	12.0	25
N. B. Report of flood in Susquehanna River Basin during March and April will be published in a later report.					
EAST GULF OF MEXICO DRAINAGE					
Apalachicola: Blountstown, Fla.	15	7	12	16.4	
Black Warrior:					
Lock No. 10, Tuscaloosa, Ala.	46	5	6	48.6	
Lock No. 7, Eutaw, Ala.	35	1	3	35.8	
		6	10	38.9	
Tombigbee:					
Aberdeen, Miss.	34	20	23	35.3	
Lock No. 4, Demopolis, Ala.	39	5	10	40.4	
Lock No. 3, Whitfield, Ala.	33	( <sup>1</sup> ) 6	14	42.6	
Lock No. 1, Saltpa, Ala.	31		14	31.9	11-12
Pearl:					
Jackson, Miss.	18	12	16	18.4	14-15
		18	28	22.0	24
Pearl River, La.	12	2	( <sup>1</sup> )	13.8	4
MISSISSIPPI SYSTEM					
Missouri Basin					
Big Sioux: Akron, Iowa.	12	1	8	17.4	
N. B. Report of flood in Ohio River Basin during March-May will appear in a later report.					
WHITE BASIN					
Black:					
Poplar Bluff, Mo.	14	30	22	15.7	21
Black Rock, Ark.	14	12	16	17.5	13
		19	May 6	18.0	May 2
White:					
Calico Rock, Ark.	18	11	13	21.9	12
Batesville, Ark.	23	12	14	26.3	12
Georgetown, Ark.	21	18	May 7	22.7	22-24
Des Arc, Ark.	24	22	29	24.9	24-26
Clarendon, Ark.	26	22	May 14	27.8	29-30
Arkansas Basin					
North Canadian: Yukon, Okla.	8	13	13	8.0	13
Poteau: Poteau, Okla.	21	12	13	22.3	12-13
Red Basin					
Sulphur:					
Ringo Crossing, Tex.	20	6	14	27.7	7
		24	34	20.4	24
Naples, Tex.	22	29	( <sup>1</sup> ) 18	23.7	29
		9		27.1	12
Lower Mississippi Basin					
Big Lake Outlet: Manila, Ark.	10	17	( <sup>1</sup> )	13.2	25-26
St. Francis:					
Fisk, Mo.	20	12	17	23.0	14
		18	25	23.3	22-23
St. Francis, Ark.	18	17	( <sup>1</sup> ) 22	20.9	25
Coldwater: Coldwater, Miss.	13	19		13.5	21
WEST GULF OF MEXICO DRAINAGE					
Trinity:					
Carrollton, Tex.	7		6	10.2	6
Trinidad, Tex.	28	9	16	31.0	12
PACIFIC SLOPE DRAINAGE					
San Joaquin Basin					
Mokelumne: Bensons Ferry, Calif.	12	Mar. 31	3	15.5	1
Sacramento Basin					
Feather: Nicolaus, Calif.	25	Mar. 31	Mar. 31	25.6	Mar. 31
Sacramento:					
Red Bluff, Calif.	23	Mar. 30	Mar. 31	28.0	Mar. 31
Hamilton City, Calif.	20	Mar. 31	Mar. 31	20.8	Mar. 31
Knights Landing, Calif.	30	Mar. 30	6	31.6	1
Columbia Basin					
Long Tom: Monroe, Oreg.	10	( <sup>1</sup> )	1	10.4	

<sup>1</sup> Continued from preceding month.

<sup>2</sup> Continued at end of month.

## WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, WILLIS E. HURD acting in charge]

## NORTH ATLANTIC OCEAN, APRIL 1940

By H. C. HUNTER

**Atmospheric pressure.**—The average atmospheric pressure during April 1940 showed only slight departures from normal over the entire North Atlantic Ocean, with extremes of +1.0 and -1.9 millibars indicated at Julianehaab, Greenland, and Horta, Azores, respectively.

The highest reading thus far found for the month, 1036 millibars (30.59 inches), was reported from the American steamship *Mormacstar* during the evening of the 12th, near latitude 51° N., longitude 39° W. The lowest mark, 972.6 millibars (28.72 inches), was noted aboard the Dutch liner *Bilderdijk*, early in the afternoon of the 21st, in latitude 49°25' N., longitude 21°51' W.

TABLE 1.—Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, April 1940

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Millibars	Millibars	Millibars		Millibars	
Julianehaab, Greenland	1,011.2	+1.0	1,034	16	996	25
Horta, Azores	1,019.1	-1.9	1,031	3	996	21
Belle Isle, Newfoundland <sup>1</sup>	1,012.6	+0.4	1,032	11	988	6
Halifax, Nova Scotia	1,014.4	+0.9	1,029	11	993	22, 23
Nantucket	1,013.1	-1.8	1,028	29	987	22
Hatteras	1,016.2	+0.1	1,028	6	996	21
Bermuda <sup>2</sup>	1,018.4	-0.6	1,026	8	1,006	29
Turks Island	1,015.7	-0.9	1,019	30	1,010	21
Key West	1,017.1	+0.5	1,021	14, 29	1,011	21
New Orleans	1,015.7	-0.2	1,029	13	1,005	18

<sup>1</sup> For 23 days.

<sup>2</sup> For 22 days.

NOTE.—All data based on available observations; departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

**Cyclones and gales.**—The first half of the month was apparently less stormy than usual at the time of year, but the second half was rather more stormy. The week from 8th to 14th is indicated as the least disturbed portion of the month.

A low which was over the region of the Great Lakes on

the morning of the 4th advanced to Newfoundland during the ensuing 48 hours, with a notable gain in energy. The Danish S. S. *Frode*, within the influence of this cyclone on the 6th, noted a wind of force 11. During the next few days the low traveled to the northeastward, losing much of its energy, as far as available reports indicate.

On the morning of the 19th two cyclones of considerable strength were charted, one over the Gulf of St. Lawrence and the other to the northwestward of the Azores. By the evening of the 20th these had united near 45° N., 30° W., to form a storm of greater energy than either low had displayed hitherto. The Dutch steamer *Bilderdijk*, on the 21st, noted unusually low barometer and wind of force 11. The movement of this storm during the 21st and the next few days was apparently toward the east.

On the morning of the 26th there was a low of slight energy a short distance east of Florida, moving slowly to northeastward. By the 28th there had been some gain in strength and the position was not far to northeastward of Bermuda. On this day and the 29th, as a result of the proximity of this low to a large-area high extending from Newfoundland to the Carolinas, many vessels near the eastern coast of the United States encountered very strong winds. The American S. S. *Washington* estimated force 12, the only instance known of such wind over the North Atlantic this month. The high consolidated toward the southwest end of the area it had covered and lost some strength before the month closed, while the low, moving but slightly, likewise decreased in energy.

**Fog.**—From reports at hand, indications are that fog was most plentiful over the coastal waters between Cape Cod and Hatteras. Occurrences of fog in that area were recorded on 12 days during the month. Two instances were noted in the Gulf of Mexico, the first on the 3d a short distance to the southeast of Galveston and the second on the 25th just west of Key West.

Fog was reported also on 7 days during the month over the central ship route between Sable Island and Horta. Elsewhere over the ocean only scattered fog reports were received from ships during the month.

## OCEAN GALES AND STORMS, APRIL 1940

Vessel	Voyage		Position at time of lowest barometer		Gale began April	Time of lowest barom-eter, April	Gale ended April	Lowest barom-eter	Direction of wind when gale began	Direction and force of wind at time of lowest bar-ometer	Direction of wind when gale ended	Direction and high-est force of wind	Shifts of wind near time of lowest bar-ometer
	From—	To—	Latitude	Longi-tude									
NORTH ATLANTIC OCEAN													
Campbell, U. S. C. G.	On station		35 36 N.	53 48 W.		10p, 3		1,011.0		N, 6	NNW	NW, 8	
Excalibur, Am. S. S.	New York	Genoa	40 00 N.	45 24 W.	3	3a, 4	4	997.6		SSW, 6		N, 8	
Tuscaloosa City, Am. S. S.	Gibraltar	Baltimore	34 48 N.	63 54 W.	5	2p, 5	5	1,010.0	SSW	WSW, 7	S	WSW, 8	
Frode, Dan. S. S.	Bristol	Norfolk	40 24 N.	60 06 W.	6	2a, 6	7	1,006.3	WNW	W, 6	WNW	WNW, 11	None.
Campbell, U. S. C. G.	On station		35 36 N.	53 24 W.	5	1p, 6	6	1,013.5	SSW	SW, 5	SW	SSW, 9	
Washington, Am. S. S.	New York	Gibraltar	40 00 N.	61 45 W.	6	6p, 7	8	1,013.9	WSW	W, 9	NW	NW, 9	
Examiner, Am. S. S.	Gibraltar	New York	36 12 N.	53 18 W.	7	12p, 7	8	1,013.5	W	NW, 8	NW	NW, 9	
Bibb, U. S. C. G.	Norfolk	Station 2	37 12 N.	69 48 W.	9	2p, 9	10	1,003.1	S		SSW	S, 9	
Examiner, Am. S. S.	Gibraltar	New York	37 00 N.	62 24 W.	9	4a, 10	10	1,012.3	S	S, 8	SW	S, 9	
Ostende, Belg. S. S.	Tampico	Galveston	22 48 N.	97 30 W.	11	12m, 11	12	1,014.3	N	ESE, 4	N	NNW, 9	
El Almirante, Am. S. S.	Galveston	Baltimore	28 18 N.	92 18 W.	12	6a, 12	12	1,023.6	N	N, 7	N	N, 8	
Sahale, Am. S. S.	Gibraltar	do	34 27 N.	68 11 W.	13	12m, 13	14	1,006.3	S	WSW, 8	NW	NW, 8	
Bergensfjord, Nor. S. S.	Bergen	New York	41 30 N.	61 48 W.	13	10p, 13	13	989.3	SSE	S, 9	W	S, 9	S-W.
Detliffes, Icel. S. S.	New York	Reykjavik	63 30 N.	26 36 W.	15	5p, 15		1,007.5		S, 10		S, 10	
Montoso, Am. S. S.	do	Jaboa, P. R.	35 18 N.	74 54 W.	15	8p, 15	16	1,008.5	SW	SW, 8	SW	SW, 8	
Duane, U. S. C. G.	On station 1		39 06 N.	59 06 W.	16	4a, 16	16	1,010.8	W	W, 8	NNW	W, 8	
Mexico, Am. S. S.	Vera Cruz	Havana	20 00 N.	94 30 W.	18	6a, 18	18	1,003.0	N	SSW, 3	N	N, 7	
Costa Rica, Du. S. S.	Antwerp	La Guaira	32 30 N.	53 36 W.	19	6p, 19	19	1,006.6	SW	WSW, 8	NW	WSW, 9	WSW-NW.
Bibb, U. S. C. G.	Station 2	Azores	38 06 N.	41 54 W.	20	5p, 20	21	1,001.7	WNW	WNW, 9	WNW	NW, 10	
Pan Kraft, Am. S. S.	Philadelphia	New Orleans	32 18 N.	79 48 W.	21	7a, 21	21	1,001.4		W, 6		W, 8	
Mobil Oil, Am. S. S.	Providence	Beaumont	29 06 N.	72 30 W.	21	12m, 21	22	989.8	NE	NE, 4	NW	NW, 8	NE-NW.
Bilderdyk, Du. S. S.	Antwerp	New York	49 25 N.	21 51 W.	20	2p, 21	22	972.6	ENE	ENE, 8	NW	NNW, 11	
Delfina, Am. S. S.	Aguadilla	Boston	41 30 N.	69 20 W.	20	4a, 22	22	983.4	SSW	N, 5	NNE	NNE, 9	
Poelan Tello, Du. M. S.	Capetown	do	41 12 N.	69 00 W.	21	8a, 22	22	982.5	SSW	NNW, 6	N	N, 9	
Duane, U. S. C. G.	On station 1		38 42 N.	58 36 W.	23	10p, 22	24	988.8	WSW	SW, 7	W	W, 8	
Leto, Du. S. S.	Rotterdam	Norfolk	49 06 N.	15 18 W.	22	11a, 23	22	989.2	SE	SW, 6	SW	SW, 9	
Uruguay, Am. S. S.	Trinidad	New York	28 18 N.	68 52 W.	28	2p, 27	29	1,010.2	NNW	WNW, 5	NNE	N, 8	
Duane, U. S. C. G.	On station 1		39 18 N.	58 12 W.	28	10p, 28	29	1,006.1	ENE	ENE, 9	ENE	ENE, 9	
Golden Sword, Am. S. S.	Bermuda	Baltimore	33 30 N.	67 24 W.	28	10p, 28	29	1,000.0	WNW	WNW, 8	N	WNW, 8	None.
Andrea F. Luckenbach, Am. S. S.	Colon	New York	30 51 N.	74 28 W.	28	12p, 28	29	1,015.2	N	N, 7	NNE	N, 9	
Washington, Am. S. S.	Gibraltar	do	38 30 N.	65 20 W.	28	—, 28	28	992.6	ESE	NE, 12	NNW	NE, 12	
Darien, Pan. S. S.	St. John, N. B.	Kingston	36 47 N.	68 51 W.	28	—, 28	29	1,008.1	NE	NNE, 9	N	N, 10	None.
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Admiral Halstead, Am. S. S.	Hondagua	San Francisco	30 12 N.	163 45 E.	1	11a, 1	3	1,013.0	SW	SW, 8	NW	SW, 8	
Dagmar Salen, Swed. S. S.	Tandoc, P. I.	Los Angeles	36 06 N.	162 18 E.	1	5p, 1	4	999.1	W	W, 8	WNW	WNW, 9	
San Ramon Maru, Jap. M. S.	Los Angeles	Osaka	33 49 N.	178 30 E.	1	4a, 2	3	1,003.1	SW		NW	W, 9	
Corilla, Du. S. S.	Shimonoseki	San Francisco	43 00 N.	171 12 W.	1	12m, 3	2	978.6	SSE	SE, 4	SW	SSW, 10	SSE-SW.
West Cusseta, Amer. S. S.	Tacoma	Shanghai	43 25 N.	165 20 E.	2	2a, 2	3	981.7	NNW	NNW, 8	NW	NW, 10	
Gertrude Maersk, Dan. M. S.	San Pedro	Yokohama	30 50 N.	175 50 E.	3	6a, 2	3	1,014.6	WNW	WSW, 7	NW	WNW, 8	WSW-WNW.
Antinous, Am. S. S.	Honolulu	Kobe	33 24 N.	142 06 E.	3	9p, 3		1,004.4		SSW, 9		SSW, 9	
City of Alma, Amer. S. S.	Nanaimo	Kobe	35 42 N.	143 18 E.	3	1a, 4	4	998.8	NW	SW, 10	WNW	SW, 11	SSW-WSW.
Toa Maru, Jap. M. S.	Los Angeles	Nagoya	34 42 N.	167 30 E.	3	1a, 3	8	1,005.1		W, 7		W, 9	
West Cusseta, Am. S. S.	Tacoma	Shanghai	39 38 N.	165 20 E.	5	2p, 5	5	993.6	WSW	WSW, 8	WNW	WSW, 10	Steady.
Arizona, U. S. S.	San Pedro	Lahaina, T. H.	35 10 N.	136 35 W.	5	1a, 6	6	1,010.0	S	S, 8	S	S, 8	
Washington, Am. S. S.	Vladivostok	Portland, Ore.	43 36 N.	163 18 W.	6	1p, 6	6	979.3	SE	ESE, 10		ESE, 10	
Jefferson Myers, Am. S. S.	Yokohama	Portland, Ore.	39 30 N.	153 40 E.	6	3a, 7	7	980.0	ESE	SSE, 8	NW	N, 10	
Corneville, Nor. M. S.	Hong Kong	San Pedro	38 20 N.	165 50 W.	6	4p, 7	8	985.3	S	W, 10	NW	WSW, 11	
West Cusseta, Am. S. S.	Tacoma	Shanghai	40 02 N.	161 20 E.	7	12m, 7	7	978.0	SE	SW, 11	NW	NW, 12	
Kyusyu Maru, Jap. M. S.	Los Angeles	Yokohama	34 54 N.	162 30 E.	7	11p, 7	7	1,013.2		W, 8		W, 8	
Mindanao, Phil. S. S.	Manila	Los Angeles	35 24 N.	167 24 E.	7	11a, 7	7	1,006.4		WNW, 8		WNW, 8	
Daini Ogura Maru, Jap. M. S.	Yokohama	San Francisco	37 48 N.	165 06 W.	8	1p, 8	8	987.6	WSW	W, 8	W	W, 8	
Delarof, Am. S. S.	Carayan	San Francisco	30 42 N.	162 42 E.	12	3a, 13	13	1,002.7	WNW	WNW, 11	NNW	WNW, 11	
Black Falcon, Am. S. S.	Balboa, C. Z.	Wilmington, Calif.	14 30 N.	93 30 W.	13	4p, 13	14	1,008.3	NW	NNW, 8	N	NNW, 8	
Washington, Am. S. S.	Vladivostok	Portland, Ore.	49 12 N.	148 18 W.	16	2a, 16	16	986.8		SSW, 8		SSW, 8	
Nitiei Maru, Jap. S. S.	Kure, Japan	Los Angeles	45 50 N.	154 40 E.	19	2a, 20	20	985.4	ENE	NNE, 9	WNW	NNE, 9	ENE-NNE.
U. S. A. T. Meigs	Manila	San Francisco	44 12 N.	166 30 E.	20	8p, 20	22	993.1	SE	SW, 10	WNW	SW, 10	SW-W.
Jeff Davis, Am. M. S.	Hong Kong	San Pedro	40 00 N.	177 00 W.	22	6a, 22	23	1,006.1	W	W, 7	WNW	W, 8	
U. S. A. T. Meigs	Manila	San Francisco	47 19 N.	169 12 W.	24	12m, 24	24	1,012.5	SW	SW, 10	WSW	SW, 10	SW-WSW.
San Ramon Maru, Jap. S. S.	Osaka	Los Angeles	44 46 N.	175 32 E.	24	12m, 24	24	973.2	NE	NNW, 8	W	NNW, 8	NW-NNW.
San Pedro Maru, Jap. S. S.	Yokohama	Los Angeles	41 48 N.	156 12 E.	28	10a, 29	29	1,003.1		SE, 8		SE, 8	
Yaka, Am. S. S.	Manila	San Francisco	35 54 N.	175 30 W.		12 p., 30		1,032.9		ENE, 8		ENE, 8	

<sup>1</sup> Position approximate.  
<sup>2</sup> Barometer uncorrected.

## NORTH PACIFIC OCEAN, APRIL 1940

By WILLIS E. HURD

**Atmospheric pressure.**—An unusual development for April occurred this month in the Aleutian Low. At Dutch Harbor, usually at or near the center of the great Pacific cyclone, the average pressure was 995 millibars (29.38 inches), which is 13.5 millibars (0.40 inch) below the April normal. This average at the station is the lowest of record for April during the 25-year period 1916-40.

East and west of the Aleutians, as shown by the averages at Kodiak and Petropavlovsk, pressures were higher than the April normal. Elsewhere on the ocean near normal pressures prevailed.

High pressure was centered near Midway Island, where the average barometer, 1,019.7 millibars (30.11 inches), showed only an unimportant depression from the normal. The high extended from the entire west coast of the United States southwestward across the Hawaiian Group

and from there westward to the easternmost archipelagos of Japan.

TABLE 1.—Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, April 1940, at selected stations

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Millibars	Millibars	Millibars		Millibars	
Point Barrow <sup>1</sup>	966.0	-13.5	1,023	29	963	24
Dutch Harbor	966.8	-12.0	1,018	29	992	1
Kodiak	1,010.7	+3.2	1,019	14	989	10
Juneau	1,014.2	-0.4	1,031	21	990	16
Tatoosh Island	1,017.6	+1.7	1,028	20	1,004	7
San Francisco	1,016.9	-0.7	1,023	29	1,006	1
Mazatlan	1,011.8	-0.4	1,015	21	1,006	18
Honolulu	1,016.6	-1.4	1,021	17	1,010	10
Midway Island	1,019.7	-0.3	1,031	16	1,008	29
Guam	1,013.0	+0.8	1,016	16, 19, 28	1,006	17, 18
Manila	1,011.2	+1.4	1,014	7	1,006	27
Hong Kong	1,013.5	+1.6	1,019	14	1,010	25
Naha	1,015.4	+2.2	1,021	9, 14	1,006	2
Tititima	1,016.1	+1.2	1,023	11	1,003	4
Petropavlovsk	1,010.8	+1.7	1,024	22, 24	988	15

<sup>1</sup> Data incomplete.

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

**Extratropical cyclones and gales.**—A greater than usual amount of cyclonic activity for April occurred over northern waters of the ocean. The result, in addition to the great deepening of the Aleutian Low, was considerable storminess which affected the northern and middle steamer routes, particularly to the westward of the 160th meridian of west longitude. To the eastward of the meridian, ships reported few gales, and those mostly of force 8 only. Among these was a fresh gale on the 26th off the California coast, and another off the northwest coast of Washington on the 30th.

The principal stormy period of the month was that of the 1st to 8th, with three distinct cyclones involved. The earliest appeared east of the Kuril Islands on the 1st, then advanced into the Aleutian region where it remained for several days with slow rate of movement, centered to the southward of the islands. In this storm, vessels reported gales of force 8-9 within the region 30°-36° N., 160°-165° E., on the 1st, and of force 8-10 over more widely scattered localities to northward and eastward on the 2d. During the 3d to 6th gales were scattered through the cyclone area, with the most important, an east-southeasterly wind of force 10, lowest barometer 979.3 millibars (28.92 inches), encountered by the American steamer *Washington* near 49° N., 165° W. The strongest local wind reported in the cyclone occurred on the 7th near 38° N., 166° W., where the Norwegian motorship *Corneville* ran into a westerly gale of force 11, lowest barometer 986.3 millibars (29.13 inches).

The second cyclone of the period lay east of central Japan on April 3 and 4, causing stormy weather on both days, with a maximum wind force of 11 on the early morning of the 4th near 36° N., 143° E., barometer 986.8 millibars (29.14 inches), reported by the American steamer *City of Alma*. The cyclone moved eastward and by the 5th was causing locally heavy weather near 39° N., 165° E., where the American steamer *West Cusseta* encountered a westerly gale of force 10.

The third cyclone of the period entered northwestern waters on the 6th, and by the 7th showed considerable intensity over the waters midway between Japan and the western Aleutians. Pressures below 982 millibars (29 inches) were observed over a considerable area, with north to northwest gales of force 10-12 occurring near

the 40th parallel between approximate longitudes 153° and 162° E. The one gale of the month to attain hurricane intensity was encountered by the *West Cusseta* near 40° N., 161° E., on the 7th. The vessel, steaming westward, had passed through the storm of the 5th, only to enter the succeeding storm two days later. Thereafter storm energy abated generally, and by the 8th and 9th only a few scattered gales of force 8, occurring along the central-latitude steamer routes in midocean, were reported.

The next locally stormy weather occurred on the 13th. The east-bound American steamer *Delarof*, at 3 a. m. of that date reported a west-northwest gale of force 11, with lowest barometer depressed only to 1,002.7 millibars (29.61 inches), near 31° N., 163° E. This is the only gale of record in connection with the cyclone, which was then central northwest of Midway Island.

The period May 20-24 was moderately stormy on northern waters, to the westward of longitude 160° W., with a cyclone strongly developed to the immediate southward of the Aleutian Islands. On the 20th a further cyclone, central well east of the Kuril Islands, was moving rapidly toward midocean. In this storm gales of force 9 and 10 occurred between the Kurils and longitude 170° E., north of the 40th parallel. The strongest gale, of force 10, from the southwest, was reported by the U. S. A. T. *Meigs*, in 44°12' N., 166°30' E., with the lowest barometer reading of the month, 963.1 millibars (28.44 inches). On the 21st this storm joined with the Aleutian cyclone. From the 22d to 24th scattered gales occurred between about latitude 37° N., and the Aleutians, longitudes 175° E., and 170° W., of which the most intense, of force 10 from the southwest, was experienced by the transport *Meigs* on the 24th, near 47° N., 169° W.

**Tehuantepecers.**—Northerly gales of force 8 occurred in the Gulf of Tehuantepec on the 13th and 14th.

**Typhoons.**—A report on a depression and a typhoon in the Far East, prepared by the Rev. Bernard F. Doucette, Weather Bureau, Manila, P. I., appears below.

**Fog.**—In east longitudes only 4 days were noted by ships as having fog. Along the northern routes in west longitudes 11 days had fog, but they were scattered over a wide strip of ocean, between the 5th and 23d, with no more than 3 foggy days in any one 5° square. Some 10° to 15° west of the California coast there was fog on the 9th and 10th. From Queen Charlotte Island northward and across the Gulf of Alaska fog was reported on 4 days. In coastal waters fog was noted on 1 day off Washington; on 8 days off California; and on 6 days off Lower California.

#### TYPHOONS AND DEPRESSIONS OVER THE FAR EAST, APRIL 1940

BERNARD F. DOUCETTE, S. J.

[Weather Bureau, Manila, P. I.]

**Depression, April 10-14, 1940.**—A depression, apparently of minor importance, formed over the ocean regions near the western Caroline Islands. It moved westerly, passing close to and south of Yap, and disappeared over the ocean about 250 miles west-northwest of Palau.

**Typhoon, April 25-May 1, 1940.**—A typhoon, violent over a small area, appeared close to and east of central Mindanao during the early morning hours of April 26. It moved rapidly in a northwesterly direction across northeastern Mindanao to the Mindanao Sea where it inclined to the west. During the evening hours of the same day it passed between Negros Island and the northern coast of Mindanao, apparently weakening. It

crossed the Sulu Sea, April 27, and passed about 30 miles south of Puerto Princesa between midnight and dawn, April 28. It moved west or west-northwest across the China Sea to the regions east of southern Indochina and filled up gradually south of the Paracel Islands and Reefs, apparently of minor intensity during these days.

From the observations received from Yap, there is no indication that this storm formed near that locality, or that it formed east or southeast of, and then moved past, the station. It may have formed over the regions adjacent to the Palau group of islands, but observations from Palau are not available for clearing up this point. The 6 a. m. observations from eastern Mindanao stations (not all were received on time) showed a fall of pressure which indicated that a depression might be forming east of Mindanao, and a warning, with this information, was sent to southern Philippine Island stations. Late in the forenoon of April 26, a message from the captain of the S. S. *Tjileboet* was received at the observatory, and is given herewith:

"4 a. m. Manila time, April 26, approximate position 8°30' N., 127°00' E. Narrow but violent typhoon passing south of us, lowest barometer reading 738.8 mm., wind northeast, 10, to south-southeast, 12; heavy swell, moderate sea. Have been under influence from midnight till 7 a. m." (738.8 mm.=985.0 mb.) Then observations from Port Lamon arrived, the data showing that the typhoon center had passed close to and south of the station. A value of 735.23 mm. (980.2 mb.), gravity correction applied, with northwest winds, force 11, was the minimum pressure, recorded at 6 a. m. No reports of pressure below 750.0 mm. (999.9 mb.) were received from any weather-bureau station while the typhoon moved toward the China Sea. The following observation from the S. S. *Don Isidro* was received at the observatory, April 27: "3 a. m. April 27, lat. 8°53' N., long. 122°11' E., bar. 747.5 mm.; temperature 82°; wind northeast by north, force 5; squally weather; rough sea; poor visibility." (747.5 mm.=996.6 mb.) The M. S. *Aloha*, at 6 a. m. April 28, experienced west winds, force 9, with a minimum pressure of 746.7 mm. (995.7 mb.) when anchored at latitude 9°00' N., longitude 117°30' E. This observation was not received at the observatory until the ship reached Manila.

Three lives were lost when the motorboat *Fookien* sank near Jonteza, Lianga (approximately latitude 8°38' N., longitude 126°05' E.). Towns along the coast of eastern and northern Mindanao suffered from strong winds, of short duration fortunately, and heavy rains.

After April 22, at Guam, the upper winds gave no indication of any disturbance forming over or near those regions, the winds varying from northeast to southeast and never reaching velocities of 50 k. p. h. Observations from Menado and Makassar, Celebes Island, stations of the Netherland East Indies network, were not received. Over the Philippines, it was impossible to obtain any upper air wind data over Cebu, April 26, because of rain. Before the typhoon appeared, winds from the north, northeast, and east directions were reported, under 50 k. p. h.; but strong southeast quadrant winds, as high as 70 k. p. h., occurred over Cebu April 27, decreasing quickly to values below 40 k. p. h. on April 28 and 29. At Zamboanga, the predominating directions were east and southeast until the afternoon of April 25, when north-northeast, north, and north-northwest winds, with velocities under 40 k. p. h. were reported. These directions continued on April 26, and the change to the west quadrant took place on the morning of April 27, when the typhoon center was in the Sulu Sea. The velocities, as reported, were 45 k. p. h. or less during these days. The change to the east and southeast quadrant directions came during the afternoon hours of April 28 and the morning of the 29th, when the disturbance was in the China Sea. No reports from Tarakan, Borneo, were received. When the typhoon was moving across the China Sea, there was very little evidence of a southwesterly current moving toward the center. The pilots from Medan, Sumatra, and Bandon, Thailand, seem to indicate, by the shift of the wind directions to the southwest quadrant, that the air was drawn toward the center of the disturbance rather than being forced toward the center. The velocities reported were not strong, only a very few groups of the pilots code showing values as high as 40 k. p. h. The few ships' observations from the southern part of the China Sea did not show the presence of a southwesterly current of any strength, a very good indication that the storm was weakening and filling up.

## CLIMATOLOGICAL TABLES

## CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE 1.—Condensed climatological summary of temperature and precipitation by sections, April 1940

[For description of tables and charts, see REVIEW, January, pp. 32 and 38]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	° F.	° F.		° F.				° F.	In.	In.		In.		In.
Alabama.....	62.4	-1.1	3 stations.....	89	11	Millry.....	21	13	3.57	-0.03	Waterloo.....	7.75	Thurlo w Dam.....	1.16
Arizona.....	59.1	+0.6	2 stations.....	103	12	Alpine.....	13	3	.84	+0.21	Junirine.....	5.79	3 stations.....	.00
Arkansas.....	59.9	-1.5	Mountain Home.....	95	1	2 stations.....	18	12	6.93	+2.04	Portland.....	10.74	Black Rock.....	4.28
California.....	56.5	+0.3	El Cajon.....	105	13	Flery Lake.....	0	2	1.28	-0.33	Cuyamaca.....	6.72	Brawley.....	.00
Colorado.....	44.6	+0.9	2 stations.....	90	1	Dillon.....	-18	12	1.86	-0.18	Telluride.....	4.82	Cdeyville.....	T
Florida.....	67.8	-2.0	Kissemee.....	93	6	Mason.....	24	13	2.77	-0.11	Gainesville.....	6.91	Ocala.....	.39
Georgia.....	61.6	-1.7	Athens No. 2.....	94	2	Blairsville.....	22	16	3.03	-0.80	Clayton.....	6.40	Savannah No. 1.....	1.39
Idaho.....	46.7	+1.6	Glenns Ferry.....	87	13	Pelton's Ranch.....	8	30	2.18	+0.76	Deception Creek.....	6.05	Porthill.....	.59
Illinois.....	51.0	-1.3	McLeansboro.....	89	1	2 stations.....	18	12	4.08	+0.56	Cairo.....	7.92	Roberts.....	1.36
Indiana.....	49.1	-2.6	Shoals.....	91	3	Salamonia.....	13	12	5.58	+1.96	Columbus.....	9.86	Albion.....	1.70
Iowa.....	47.5	-1.2	3 stations.....	89	14	Sibley.....	10	11	3.22	+0.49	Bedford.....	4.85	Britt.....	1.70
Kansas.....	54.3	-0.4	Syracuse.....	97	1	Oakley.....	8	12	2.97	+0.44	Toronto.....	7.72	Syracuse.....	.38
Kentucky.....	54.1	-2.0	Williamsburg.....	89	2	2 stations.....	19	13	4.88	+0.88	Beaver Dam.....	8.44	Pikeville.....	2.57
Louisiana.....	66.0	-1.0	5 stations.....	90	1	do.....	29	13	9.44	+4.72	St. Joseph.....	21.80	Crowley.....	4.95
Maryland-Delaware.....	48.1	-4.0	Cumberland, Md.....	83	29	Oakland, Md.....	15	13	5.78	+2.20	La Plata, Md.....	8.08	Delaware Breakwater, Del.....	3.68
Michigan.....	39.3	-2.8	Alma.....	82	30	Dukes.....	-3	14	1.97	-0.48	Manistee.....	3.30	St. Ignace.....	.81
Minnesota.....	40.4	-2.5	3 stations.....	80	14	Baudette.....	-4	11	2.39	+0.49	Winnibgoshish.....	5.16	Montevideo.....	.68
Mississippi.....	63.0	-1.5	Columbia.....	90	12	2 stations.....	25	13	6.96	+2.04	Port Gibson.....	15.92	Columbus.....	2.06
Missouri.....	54.0	-1.1	3 stations.....	92	1	do.....	15	12	4.41	+0.47	Dean.....	8.96	Bowling Green.....	1.28
Montana.....	41.8	-1.3	Ballantine.....	82	13	Summit.....	-30	11	2.19	+1.16	Billings No. 2.....	5.77	Boulder.....	.55
Nebraska.....	48.3	-0.9	3 stations.....	93	11	3 stations.....	0	12	2.24	-0.12	Fort Robinson.....	5.09	Benkelman.....	.17
Nevada.....	49.5	+1.5	Overton.....	99	14	Kimberly.....	11	7	1.24	+0.46	Lamoille.....	4.94	Searchlight.....	.00
New England.....	40.0	-3.6	2 stations.....	80	30	Ft. Kent, Maine.....	-9	6	5.28	+1.90	Lake Konomoc, Conn.....	8.56	Burlington, Vt.....	1.88
New Jersey.....	45.5	-4.1	do.....	79	30	Charlottesville.....	15	15	5.62	+1.97	Elizabeth.....	6.71	Tuckerton.....	3.64
New Mexico.....	51.4	-0.2	do.....	95	120	Lake Alice (near).....	0	12	.06	-0.20	Crossroads.....	2.60	2 stations.....	.00
New York.....	40.7	-3.4	5 stations.....	80	129	Wanakena.....	8	3	3.87	+0.86	Walden.....	7.13	Raquette.....	1.55
North Carolina.....	56.3	-1.6	Hot Springs.....	91	2	Mount Mitchell.....	1	13	3.46	-0.15	Mount Mitchell.....	10.34	Gastonia.....	1.74
North Dakota.....	37.8	-3.6	Edgeley.....	78	14	Langdon.....	-9	11	2.22	+0.80	Alpha.....	5.82	Valley City.....	.36
Ohio.....	46.5	-3.2	3 stations.....	83	13	Lima.....	12	12	5.53	+2.32	Mount Healthy (near).....	9.72	Bowling Green.....	3.06
Oklahoma.....	59.9	-0.4	2 stations.....	95	1	2 stations.....	10	12	5.03	+1.70	Bristow.....	8.84	Goodwell.....	1.02
Oregon.....	48.3	+1.1	McKenzie Bridge.....	88	12	do.....	15	11	2.08	+0.10	Valsets.....	9.12	Paisley.....	.26
Pennsylvania.....	45.1	-3.4	2 stations.....	82	13	Mount Pocono.....	9	14	5.30	+1.84	Ardmore.....	7.97	Erie.....	3.12
South Carolina.....	60.6	-1.6	Waterboro.....	94	2	Caesars Head.....	18	13	2.07	-0.21	Caesars Head.....	4.79	Summerville.....	.64
South Dakota.....	43.3	-2.6	Mitchell.....	90	14	Lead.....	-1	11	2.70	+0.65	Ardmore.....	5.22	Pierre.....	1.17
Tennessee.....	57.1	-1.5	Coldwater.....	91	2	2 stations.....	18	13	4.55	+0.11	Tiptonville.....	8.39	Elizabethton.....	2.75
Texas.....	65.2	-0.9	Alice.....	103	30	do.....	10	12	3.06	+0.03	Bon Wier.....	11.21	2 stations.....	.00
Utah.....	48.7	+1.5	Moab.....	89	23	Silver Lake.....	9	16	1.46	+0.29	Silver Lake.....	4.41	Callao.....	.09
Virginia.....	52.2	-2.2	Christchurch.....	88	18	Big Meadow.....	0	13	4.34	+0.98	Pinnacles.....	7.32	Ivanhoe.....	2.07
Washington.....	50.3	+2.0	Concrete.....	87	12	2 stations.....	21	2	2.79	+0.47	Cedar Lake.....	8.89	Sunnyside.....	.25
West Virginia.....	49.2	-2.5	Logan.....	86	3	do.....	10	13	5.13	+1.55	Rowlesburg.....	8.43	Kanawha Falls.....	2.98
Wisconsin.....	40.9	-2.6	Menomonie.....	79	28	Long Lake.....	-2	13	2.50	-0.04	La Crosse.....	3.92	Medford.....	1.38
Wyoming.....	40.7	+0.5	4 stations.....	78	13	2 stations.....	-9	11	2.52	+0.94	Dome Lake.....	7.25	Jewett Ranch.....	.29
Alaska (March).....	17.9	+4.7	Tree Point.....	64	27	Pilgrim.....	-40	19	3.78	+1.08	View Cove.....	19.35	4 stations.....	T
Hawaii.....	72.2	+2.7	2 stations.....	92	13	Haleakala.....	29	22	4.46	-4.11	Power House (Wainiha).....	27.41	Olowalu.....	.00
Puerto Rico.....	75.9	+1.1	Manati.....	98	25	Guineo Reservoir.....	51	20	4.80	+0.49	Bayamon.....	12.60	Pennelias (near).....	.15

1 Other dates also.

TABLE 2.—Climatological data for Weather Bureau stations, April 1940

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind					Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month				
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. +2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch or more	Average hourly velocity	Prevailing direction	Maximum Velocity									
																								Miles per hour						Direction	Date		
New England																																	
Eastport	75	67	85	29.85	29.94	+0.01	37.0	-2.0	53	13	43	23	7	31	26	34	30	77	2.35	-0.5	13	12.3	nw.	46	ne.	21	7	10	13	6.4	10.0	0.0	
Greenville, Maine	1,070	6	117	29.82	29.94	-0.02	40.4	-2.6	64	30	47	22	14	34	24	35	30	73	7.12	+3.7	14	10.1	n.	36	se.	9	9	10	11	5.9	9.5	0.0	
Portland, Maine	103	82	117	29.82	29.94	-0.02	41.0	-2.4	78	30	50	21	14	32	44	35	30	71	4.95	+2.2	13	7.0	nw.	26	nw.	6	9	7	14	6.2	7.2	0.0	
Concord	288	54	72	29.56	29.95	-0.04	41.0	-2.4	78	30	50	21	14	32	44	35	30	71	4.95	+2.2	13	7.0	nw.	26	nw.	6	9	7	14	6.2	7.2	0.0	
Burlington	403	11	48	29.49	29.94	-0.05	39.2	-4.1	74	30	48	18	14	31	37	35	29	69	1.88	-0.3	12	9.8	n.	32	s.	11	6	6	18	7.0	6.6	0.0	
Northfield	876	12	60	28.98	29.96	-0.03	36.3	-4.0	76	30	45	13	15	27	44	33	28	74	2.40	+1.1	14	8.8	n.	27	s.	11	4	11	15	7.2	6.4	0.0	
Boston	125	106	165	29.90	29.93	-0.04	43.6	-2.8	75	30	51	26	14	36	31	38	31	68	4.58	+1.2	13	13.3	nw.	43	ne.	21	6	9	15	6.7	1.5	0.0	
Nantucket	12	14	90	29.92	29.93	-0.04	42.3	-1.1	56	19	48	30	14	37	18	39	35	81	4.97	+2.0	12	15.2	w.	39	se.	8	7	8	15	6.5	2.0	0.0	
Block Island	26	11	46	29.91	29.94	-0.04	42.1	-1.9	55	30	48	30	14	36	16	35	39	80	5.01	+1.5	13	16.3	w.	43	ne.	21	13	4	13	5.4	T	0.0	
Providence	62	215	251	29.87	29.94	-0.04	44.5	-2.1	70	30	52	27	14	37	28	38	33	71	5.30	+2.1	15	13.3	nw.	50	nw.	6	12	8	10	5.5	2.0	0.0	
Hartford	159	122	122	29.92	29.94	-0.05	43.7	-3.0	69	30	53	25	15	34	36	38	33	71	5.38	+2.0	13	10.4	n.	32	nw.	6	6	8	16	6.9	1.7	0.0	
New Haven	13	74	68	29.94	29.95	-0.04	44.9	-2.3	66	28	52	25	13	37	27	39	35	74	6.71	+3.2	16	9.9	n.	30	ne.	21	9	7	14	6.4	1.9	0.0	
Middle Atlantic States																																	
Albany	292	26	40	29.61	29.94	-0.06	41.7	-5.1	76	30	51	21	14	33	37	37	31	69	3.93	+1.5	11	11.6	nw.	36	nw.	5	4	13	13	6.8	4.4	0.0	
Binghamton	871	57	79	29.03	29.97	-0.05	42.4	-3.0	77	30	52	22	13	33	43	37	31	70	3.59	+1.1	14	7.6	nw.	24	nw.	6	4	9	17	7.4	1.5	0.0	
New York	314	415	454	29.60	29.94	-0.06	46.0	-3.4	67	30	54	25	13	38	29	40	33	65	5.41	+2.2	10	15.5	nw.	48	nw.	13	5	10	15	7.1	9.0	0.0	
Harrisburg	374	94	104	29.59	29.97	-0.05	47.6	-3.3	78	30	57	25	13	38	42	41	33	63	4.70	+2.0	11	10.0	nw.	28	se.	11	5	7	18	7.3	T	0.0	
Philadelphia	114	174	367	29.84	29.97	-0.04	48.2	-3.9	74	30	57	26	13	40	30	42	37	70	6.06	+3.0	10	13.2	nw.	40	ne.	20	6	8	16	6.5	1.2	0.0	
Reading	323	283	306	29.62	29.96	-0.04	47.4	-2.9	74	30	56	25	13	38	33	41	32	60	4.84	+1.6	8	13.0	nw.	40	ne.	20	9	8	13	6.3	1.7	0.0	
Scranton	805	72	104	29.08	29.96	-0.05	44.0	-4.1	75	29	53	22	13	35	40	38	31	64	3.76	+1.0	11	7.7	n.	33	nw.	4	5	12	13	6.6	1.5	0.0	
Atlantic City	52	37	172	29.90	29.96	-0.04	45.4	-2.4	62	19	52	26	13	39	25	41	36	74	5.84	+2.8	15	16.8	nw.	49	se.	8	7	7	16	6.5	9.0	0.0	
Sandy Hook	22	10	57	29.93	29.95	-0.04	44.7	-3.6	64	28	51	27	13	38	24	40	36	76	4.54	+1.9	12	14.2	nw.	43	ne.	20	4	9	17	7.0	5.0	0.0	
Trenton	190	89	107	29.75	29.96	-0.04	45.5	-3.3	74	30	55	25	13	38	32	41	34	64	5.24	+2.3	12	9.9	nw.	29	ne.	20	4	10	16	7.1	2.5	0.0	
Baltimore	16	100	215	29.95	29.97	-0.04	50.2	-3.4	75	30	58	28	13	42	28	43	38	70	6.99	+3.6	11	11.6	nw.	37	se.	11	4	8	18	7.1	8.0	0.0	
Washington	112	62	85	29.84	29.96	-0.06	50.8	-2.5	82	30	60	28	13	42	31	44	36	61	6.19	+2.9	12	8.4	nw.	26	nw.	22	5	11	14	6.9	5.0	0.0	
Cape Henry	18	8	54	29.94	29.96	-0.04	52.6	-2.0	85	18	61	33	13	44	37	48	44	77	6.31	+3.1	11	13.0	se.	45	nw.	21	7	11	12	6.0	3.0	0.0	
Lynchburg	686	144	194	29.23	29.98	-0.04	54.4	-2.9	81	16	66	27	13	43	41	46	38	60	4.25	+1.3	12	8.3	nw.	28	nw.	21	6	11	13	6.4	T	0.0	
Norfolk	91	80	125	29.88	29.96	-0.03	55.2	-1.6	83	18	65	30	13	45	38	48	43	71	3.37	+1.1	12	10.8	s.	32	n.	12	6	9	15	6.5	1.3	0.0	
Richmond	164	11	52	29.79	29.97	-0.05	53.6	-3.0	82	4	65	28	13	42	35	46	41	71	5.19	+1.7	11	8.9	sw.	25	ne.	12	8	8	14	6.1	2.5	0.0	
Wyrtheville	2,304	49	55	27.56	29.97	-0.06	50.8	-1.2	78	3	62	20	13	40	41	43	37	65	2.97	0.0	11	7.9	w.	32	nw.	3	7	10	13	6.4	T	0.0	
South Atlantic States																																	
Asheville	2,253	80	104	27.64	29.99	-0.04	53.7	-2.2	85	2	66	23	13	42	44	45	39	65	3.26	+1.2	10	10.0	nw.	31	se.	19	6	11	13	6.6	2.0	0.0	
Charlotte	769	63	86	29.16	29.97	-0.06	59.1	-1.7	85	1	70	28	13	48	35	50	45	68	2.03	-1.3	6	8.5	sw.	26	sw.	4	7	11	12	5.9	0.0	0.0	
Greensboro	886	6	56	29.04	29.98	-0.05	55.6	-3.2	82	1	68	25	13	44	40	48	42	66	3.57	-1.1	9	9.7	sw.	29	nw.	3	7	9	14	6.3	0.0	0.0	
Hatteras	11	5	50	29.98	29.98	-0.03	56.3	-3.5	72	18	62	38	13	50	24	52	48	77	3.47	-0.1	9	15.1	n.	42	n.	12	13	10	7	4.6	0.0	0.0	
Raleigh	358	103	146	29.59	29.98	-0.05	58.0	-1.4	84	1	69	29	13	47	41	50	44	66	3.16	-0.3	7	10.0	sw.	27	se.	19	10	12	8	4.8	0.0	0.0	
Wilmington	72	73	107	29.92	29.99	-0.04	59.6	-2.4	85	4	69	34	13	50	29	53	48	69	2.39	-0.3	7	11.7	sw.	30	s.	12	9	9	12	5.4	0.0	0.0	
Charleston	48	11	92	29.96	30.01	-0.02	62.6	-1.9	86	4	71	36	13	54	30	56	51	72	1.77	-0.8	5	11.7	s.	27	w.	20	11	10	9	5.1	0.0	0.0	
Columbia, S. C.	225	70	91	29.75	29.99	-0.04	61.5	-1.8	86	1	73	30	13	50	33	52	46	64	2.09	-0.8	5	9.8	sw.	28	sw.	15	11	9	10	5.0	0.0	0.0	
Greenville, S. C.	1,040	70	78	28.88	29.98	-0.05	58.4	-2.1	84	1	70	29	13	47	35	50	46	64	1.26	-0.8	5	8.7	sw.	36	sw.	3	10	7	13	5.7	0.0	0.0	
Augusta	426	62	77	29.53	29.98	-0.05	62.7	-1.5	81	2	74	32	13	51	34	53	46	64	2.01	-1.1	6	7.0	w.	23	sw.	8	11	6	13	5.6	0.0	0.0	
Savannah	51	73	152	29.96	30.01	-0.02	64.2	-1.8	91	2	74	36	13	54	31	56	52	77	1.39	-1.2	5	12.4	sw.	32	nw.	20	12	4	14	5.1	0.0	0.0	
Jacksonville	43	86	110	29.98	30.03	-0.01	66.6	-2.1	88	2	76	35	13	57	33	59	55	73	3.28	+0.9	7	9.2	sw.	27	w.	20	10	9	11	5.1	0.0	0.0	
Florida Peninsula																																	
Key West	21	10	64	30.00	30.01	-0.01	74.6	-1.1	86	8	80	57	15	69	19	68	65	76	2.48	+1.2	3	10.9	e.	34	nw.	13	18	7	5	3.6	0.0	0.0	
Miami	25	124	168	30.00	30.03	-0.00	72.2	-0.6	84	24	78	46	14	66	24	65	60	70	0.76	-2.3	4	9.6	se.	29	w.	21	14	10	4	4.2	0.0	0.0	
Tampa	11	88	197	30.02	30.03	+0.03	69.4	-0.5	88	2	78	44	13	61	25	62	59	74	3.27	+1.3	3	11.4	w.	35	se.	19	16	13	1	3.0	0.0	0	

TABLE 2.—Climatological data for Weather Bureau Stations, April 1940—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month		
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. + 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch, or more	Average hourly velocity	Prevailing direction	Maximum velocity								
																								Miles per hour							Direction	Date
Ohio Valley and Tennessee	Ft.	Ft.	Ft.	In.	In.	In.	°F. 52.4	°F. -2.4	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	% 67	In. 5.52	In. +1.8		Miles						0-10 6.7	In.	In.		
Chattanooga <sup>1</sup>	688	71	214	29.25	29.98	-0.05	59.6	-0.7	88	2	69	28	13	50	33	51	45	69	3.86	-1.0	10	10.1	se.	30	sw.	11	6	10	14	6.4	0.0	0.0
Knoxville <sup>1</sup>	980	66	84	28.94	29.98	-0.05	57.8	-1.2	88	2	68	27	13	48	32	49	42	65	4.28	+1.1	10	6.9	w.	21	sw.	8	9	9	12	5.9	0.0	0.0
Memphis <sup>1</sup>	284	78	86	29.00	29.98	-0.05	60.6	-1.2	85	3	69	32	12	52	30	53	48	69	4.88	+1.1	13	10.2	s.	31	nw.	30	9	7	14	6.0	0.0	0.0
Nashville <sup>1</sup>	605	108	188	29.31	29.96	-0.05	57.7	-1.3	86	1	67	29	13	48	32	50	44	65	5.24	+1.1	11	11.9	s.	34	se.	29	8	7	15	6.4	0.0	0.0
Lexington	989	6	—	—	—	—	51.6	-2.7	81	15	62	24	13	41	37	—	—	—	4.81	—	14	—	—	—	—	9	7	14	6.1	0.0	0.0	
Louisville <sup>1</sup>	545	106	120	29.37	29.96	-0.05	53.8	-2.6	85	2	63	27	12	45	33	46	40	68	7.21	+3.3	9	10.5	ne.	32	s.	20	11	8	11	5.6	0.0	0.0
Evansville <sup>1</sup>	431	76	116	29.48	29.96	-0.04	54.5	-2.2	85	1	63	27	12	46	32	47	41	64	6.37	+2.5	13	11.2	s.	56	sw.	30	5	8	17	6.8	0.0	0.0
Indianapolis <sup>1</sup>	808	98	129	29.09	29.97	-0.03	49.2	-2.9	82	3	58	20	12	40	31	42	37	72	6.05	+2.4	11	9.9	e.	29	sw.	3	1	13	16	7.3	2.1	0.0
Terre Haute	575	63	149	29.33	29.96	-0.03	51.0	-2.9	82	2	61	22	12	41	34	44	37	63	6.41	+2.8	12	11.5	se.	32	ne.	19	1	8	21	8.0	4.1	0.0
Terre Haute	497	11	51	29.43	29.98	-0.03	50.1	-2.3	82	3	60	23	12	40	33	44	38	67	7.31	+4.2	11	9.5	n.	26	e.	19	5	9	16	7.0	0.0	0.0
Cincinnati <sup>1</sup>	833	90	110	29.08	29.98	-0.04	47.8	-3.4	79	3	57	22	12	39	29	41	35	68	6.31	+3.4	16	10.7	n.	37	w.	4	3	12	15	7.1	4.0	0.0
Columbus <sup>1</sup>	900	186	213	29.01	29.98	-0.05	46.9	-3.8	81	3	57	19	12	38	31	42	35	66	4.82	+1.6	16	11.9	ne.	43	w.	3	7	10	13	6.6	5.0	0.0
Dayton	2,006	61	78	27.85	29.98	-0.05	47.8	-1.9	78	29	59	17	13	35	40	40	36	75	4.66	+1.2	16	7.2	n.	32	sw.	3	3	5	22	7.9	4.1	0.0
Elkins <sup>1</sup>	637	77	84	29.28	29.97	-0.06	49.8	-3.6	82	3	60	24	13	40	35	43	35	63	4.44	+1.2	14	7.4	nw.	27	w.	13	7	9	14	6.6	2.6	0.0
Parkersburg	1,273	39	54	28.60	29.97	-0.05	46.6	-4.6	79	29	57	20	13	36	33	40	33	67	5.26	+2.3	16	11.7	nw.	41	n.	3	4	9	17	7.2	2.6	0.0
Pittsburgh <sup>1</sup>	1,273	39	54	28.60	29.97	-0.05	46.6	-4.6	79	29	57	20	13	36	33	40	33	67	5.26	+2.3	16	11.7	nw.	41	n.	3	4	9	17	7.2	2.6	0.0
Lower Lake Region							42.4	-3.0										71	3.36	+0.8									6.6			
Buffalo <sup>1</sup>	706	243	280	29.21	29.98	-0.03	40.2	-2.6	74	29	48	16	13	32	28	36	32	73	2.31	-2	13	14.0	w.	43	sw.	18	8	5	17	6.5	5.1	0.0
Canton	448	10	61	29.46	29.94	-0.03	39.3	-3.2	76	30	48	18	13	30	36	35	30	72	2.28	+1.1	13	9.1	w.	32	sw.	18	6	6	18	7.1	4.4	0.0
Ithaca	836	77	100	29.04	29.97	-0.04	42.7	-2.3	78	30	52	23	13	33	36	36	30	70	3.59	+1.1	16	10.4	nw.	29	nw.	6	5	10	15	6.8	2.8	0.0
Oswego	335	71	85	29.60	29.97	-0.04	39.8	-3.8	75	30	46	22	13	33	36	36	30	70	2.88	+5	13	10.1	w.	29	n.	12	9	7	14	6.1	1.1	0.0
Rochester <sup>1</sup>	555	86	102	29.37	29.98	-0.03	42.4	-2.5	79	29	50	22	13	35	33	36	31	71	3.30	+1.0	13	9.1	w.	34	sw.	18	6	7	17	6.8	3.7	0.0
Syracuse <sup>1</sup>	408	65	79	29.52	29.97	-0.04	42.0	-2.7	77	30	50	24	13	34	38	37	32	74	3.98	+1.5	15	8.7	nw.	24	w.	30	6	10	14	6.5	5.3	0.0
Erie	714	57	81	29.20	29.99	-0.03	41.9	-3.2	79	29	50	22	13	34	32	37	33	73	3.12	+4	12	7.9	n.	24	n.	20	5	15	10	6.1	5.5	0.0
Cleveland <sup>1</sup>	805	267	318	29.11	29.99	-0.03	43.2	-3.0	78	29	51	22	13	35	35	38	32	69	3.95	+1.5	12	14.2	ne.	43	ne.	20	7	8	15	6.4	5.3	0.0
Sandusky	629	5	67	29.31	30.00	-0.02	44.6	-2.6	77	29	53	23	13	36	30	38	33	72	4.65	+2.1	12	9.9	ne.	30	ne.	20	8	7	15	6.6	3.3	0.0
Toledo <sup>1</sup>	629	79	87	29.30	30.00	-0.01	44.0	-3.6	75	30	52	18	12	36	29	38	33	72	3.17	+5	11	10.7	e.	28	ne.	20	7	10	13	6.1	3.1	0.0
Fort Wayne <sup>1</sup>	825	69	84	29.09	29.99	-0.02	45.4	-3.0	78	3	55	18	12	36	41	38	32	68	4.47	+1.4	14	10.3	ne.	28	w.	3	5	5	20	7.3	3.1	0.0
Detroit <sup>1</sup>	626	5	78	29.32	30.01	-0.01	42.8	-3.4	77	30	52	19	12	33	33	37	31	67	2.61	+2	12	10.5	nw.	27	n.	20	7	7	16	6.8	3.4	0.0
Upper Lake Region							39.8	-1.7										70	2.29	-0.2									6.2			
Alpena	609	13	89	29.35	30.03	+0.01	38.2	-4	74	30	46	18	13	30	28	33	27	68	1.66	-6	13	11.3	nw.	31	nw.	11	9	9	12	5.5	2.0	0.0
Escanaba	612	51	72	29.38	30.06	+0.04	36.8	-1.1	55	6	45	14	12	28	26	32	27	73	1.71	-5	11	10.5	n.	28	nw.	11	8	7	15	6.1	4.5	0.0
Grand Rapids <sup>1</sup>	689	70	244	29.24	29.99	-0.02	44.3	-2.7	71	28	54	21	12	35	29	36	30	68	2.12	-6	11	12.1	n.	46	sw.	30	8	7	15	6.3	1.6	0.0
Lansing	878	5	90	29.04	30.00	-0.02	42.1	-3.5	74	30	52	20	12	32	33	37	31	69	1.42	-1.2	13	9.7	nw.	27	sw.	30	9	6	15	6.3	1.2	0.0
Ludington	637	60	66	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0
Marquette	734	44	69	29.23	30.05	+0.03	35.8	-2.0	64	28	43	14	12	29	30	33	28	76	2.98	+6	11	7.4	nw.	26	sw.	28	8	9	13	6.2	19.2	0.0
Sault Sainte Marie <sup>1</sup>	724	11	52	29.23	30.03	-0.00	36.7	-7	66	28	45	16	14	28	32	31	25	70	1.38	-8	9	8.4	nw.	30	nw.	11	10	6	14	5.7	10.1	0.0
Chicago	673	7	131	29.26	30.00	-0.00	44.6	-2.3	76	3	51	24	12	38	35	39	33	70	3.17	+4	11	12.0	ne.	34	sw.	3	6	10	14	6.7	1.1	0.0
Green Bay	617	109	141	29.34	30.02	+0.01	40.9	-2.3	67	29	49	20	12	38	28	35	29	65	2.91	+3	10	11.0	n.	30	n.	17	7	9	14	6.5	1.5	0.0
Milwaukee <sup>1</sup>	698	97	221	29.25	30.02	+0.03	41.4	-2.4	72	29	47	22	12	36	26	36	31	75	2.96	+3	9	12.7	n.	34	n.	18	8	9	13	6.3	2.5	0.0
Duluth	1,133	5	47	28.79	30.04	+0.03	37.17																									

TABLE 2.—Climatological data for Weather Bureau stations, April 1940—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind				Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month																														
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. mean min. +2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch or more	Average hourly velocity	Prevailing direction							Maximum velocity		Date																											
																														Miles per hour	Direction																												
Northern Slope																														0-10																													
Ft.																														In.		In.																											
Billings <sup>1</sup>	3,570	18	39	26.30	30.03	—	42.4	—	77	13	52	6	11	32	38	32	72	3.16	—	15	11.7	ne.	34	nw.	20	1	6	23	8.61	0.6	0.0																												
Havre	2,507	11	67	27.36	30.06	+0.13	40.6	—	77	13	50	—	11	31	45	36	30	70	1.95	+1.0	13	9.6	e.	35	w.	18	3	11	16	6.9	7.0																												
Helena	4,124	85	111	25.79	30.02	+0.05	42.4	—	75	13	52	5	11	33	35	36	30	65	1.14	+0.0	13	8.0	sw.	33	sw.	20	1	4	25	8.8	1.3																												
Missoula <sup>1</sup>	3,189	80	91			—	47.6	+2.4	76	13	58	20	11	38	44	41	34	65	1.64	+0.6	18	8.6	e.	43	ne.	10	2	8	20	7.8	T																												
Kalispell	2,973	48	56	26.93	30.00	+0.04	45.0	+1.4	73	13	55	12	11	35	37	38	31	63	1.49	+0.7	15	6.2	w.	23	n.	10	3	9	18	7.6	3.5																												
Miles City <sup>1</sup>	2,634	48	55	27.24	30.03	+0.07	42.5	—	77	13	52	8	11	33	42	37	33	75	1.92	+0.8	14	8.0	nw.	26	w.	18	2	5	23	8.3	11.6																												
Rapid City <sup>1</sup>	3,218	50	55	26.64	30.01	+0.06	41.3	—	73	27	50	7	12	33	38	36	32	77	3.06	+1.0	16	9.8	n.	30	n.	22	5	9	16	6.9	8.6																												
Cheyenne <sup>1</sup>	6,144	5	39	23.88	29.92	—	42.0	+1.1	74	14	54	9	12	30	49	34	27	61	1.36	—0.6	9	13.7	nw.	43	n.	11	1	13	16	7.7	9.5																												
Lander	5,352	60	68	24.59	29.92	—	43.6	+1.2	71	13	55	14	11	33	39	37	30	64	3.44	+1.4	10	6.0	e.	41	sw.	20	3	11	16	7.3	21.3																												
Sheridan <sup>1</sup>	3,790	10	47	26.01	30.00	—	42.0	—	76	13	53	7	12	31	55	37	32	73	3.87	+2.0	14	6.6	nw.	22	nw.	21	2	6	22	8.1	13.9																												
Yellowstone Park	6,241	12	46	23.84	30.04	+0.08	38.2	+1.6	64	13	49	10	11	27	37	32	27	68	1.94	+0.8	13	7.6	sw.	25	sw.	26	4	9	17	7.2	7.6																												
North Platte <sup>1</sup>	2,787	11	51	27.04	29.94	+0.02	48.4	—	86	14	60	12	12	36	45	40	32	64	—	—	9	10.3	n.	30	nw.	3	11	8	11	5.0	1.0																												
Middle Slope																														53.0		—0.4				60		3.14		+0.8																			
Denver <sup>1</sup>	5,332	106	113	24.62	29.89	—	48.3	+1.2	77	20	60	12	12	37	50	38	28	56	1.53	—0.5	9	8.1	s.	36	n.	22	2	11	17	7.3	3.3																												
Pueblo <sup>1</sup>	4,806	79	86	25.11	29.89	+0.01	50.2	+1.1	82	14	64	9	12	37	45	40	31	58	1.64	+0.2	6	7.2	e.	32	w.	1	9	12	9	5.3	9.9																												
Concordia	1,392	50	58	28.47	29.85	+0.02	51.8	—	90	1	62	19	12	42	42	44	37	62	1.61	—0.8	10	10.6	n.	33	nw.	3	7	9	14	6.6	1.3																												
Dodge City	2,509	10	86	27.31	29.90	—	53.3	—	88	1	66	18	12	41	42	45	37	60	3.54	+1.6	9	14.4	ne.	37	s.	27	11	8	11	5.3	1.8																												
Wichita <sup>1</sup>	1,392	85	93	28.44	29.91	—	54.6	—	87	1	65	21	12	44	37	47	40	66	6.15	+3.2	11	11.5	se.	29	sw.	10	11	8	11	5.4	2.0																												
Oklahoma City <sup>1</sup>	1,304	10	47	28.53	29.90	—	59.8	—	92	16	70	25	12	49	37	50	42	61	4.46	+1.2	7	11.1	s.	26	n.	11	10	9	11	5.5	0.0																												
Chadron, Nebr.	3,439	4	58																																																								
Southern Slope																														62.6		—0.2				52		1.46		—0.4																			
Abilene <sup>1</sup>	1,750	10	56	28.08	29.88	—	65.4	+1.0	98	21	78	28	12	52	41	52	42	55	1.53	—1.2	6	12.1	s.	30	n.	11	9	16	5	5.1	0.0																												
Amarillo <sup>1</sup>	3,604	10	49	26.25	29.88	+0.01	57.0	+1.2	89	1	71	16	12	43	45	44	34	57	1.10	—0.7	10	10.7	w.	35	w.	16	11	15	4	4.6	6.9																												
Del Rio	960	63	71	28.87	29.85	—	69.2	—	97	30	81	40	13	58	40	58	50	57	1.98	+0.2	4	10.0	se.	32	nw.	4	9	12	9	5.6	0.0																												
Roswell	3,506	75	85	26.29	29.87	+0.02	59.0	—	88	20	74	27	12	44	48	45	29	41	1.23	+0.3	2	9.4	s.	43	se.	26	15	10	8	4.2	8.7																												
Southern Plateau																														58.8		+2.0				36		6.38		—0.1																			
El Paso <sup>1</sup>	3,916	82	101	25.97	29.83	—	63.6	+2.2	87	20	77	36	6	50	40	45	24	26	—0.2	—0.2	1	9.6	w.	31	sw.	16	17	12	1	3.0	0.0																												
Albuquerque <sup>1</sup>	5,314	5	34	24.67	29.84	—	64.4	+1.4	84	20	69	27	12	40	37	40	25	38	—0.1	—0.4	6	11.2	s.	44	se.	5	7	10	13	6.0	T																												
Santa Fe	7,013	38	53	23.18	29.88	+0.04	47.8	+1.1	73	20	60	22	12	35	36	36	23	43	—0.5	—0.5	5	7.2	w.	21	w.	27	10	7	13	5.5	4.6																												
Flagstaff	6,907	10	59	23.29	29.83	—	44.6	+2.4	73	13	59	22	11	30	47	36	27	—	—	1.71	+0.6	7	8.9	sw.	34	s.	15	7	16	7	5.3	13.3																											
Phoenix <sup>1</sup>	1,112	39	87	28.70	29.85	—	70.0	+3.0	95	13	84	47	2	56	39	52	35	35	—0.9	—0.3	3	6.5	e.	24	s.	23	10	10	10	4.8	0.0																												
Yuma	142	9	54	29.72	29.87	—	72.2	+2.7	102	12	85	50	3	57	40	55	41	39	—0.1	—0.1	0	5.9	sw.	20	w.	15	27	3	0	1.4	0.0																												
Independence	3,957	5	26				59.0	+3.9	85	20	74	32	2	44	40	43	25	—	—	0.15	0.0	1		n.						0.0	0.0																												
Middle Plateau																														59.7		+2.3				52		1.19		+0.2																			
Ely, Nev. <sup>1</sup>	5,077	5	36				50.2	+2.7	81	13	63	30	5	37	40	39	30	57	—0.8	+0.3	4	7.2	w.	24	w.	7	8	15	7	6.0	T																												
Reno <sup>1</sup>	4,400	61	76	25.57	29.90	+0.02	50.2	—	81	13	63	30	5	37	40	39	30	57	—0.8	+0.3	4	7.2	w.	24	w.	7	8	15	7	6.0	T																												
Tomopah	6,080	12	26				48.8	+2.1	82	13	63	26	2	35	45	39	28	53	—0.97	+0.1	9	7.7	sw.	31	nw.	14	6	12	12	6.4	T																												
Winnemucca	4,344	18	56	25.58	29.87	—	47.8	+1.8	77	20	63	22	11	32	45	38	25	48	—0.70	—0.2	7	10.6	sw.	38	s.	15	6	10	14	6.5	1.0																												
Modena	5,473	10	46	24.55	29.86	—	47.8	+2.8	77	20	63	22	11	32	45	38	25	48	—0.70	—0.2	7	10.6	sw.	38	s.	15	6	10	14	6.5	1.0																												
Salt Lake City <sup>1</sup>	4,227	86	210	25.68	29.92	—	54.4	+2.0	80	20	66	33	3	43	36	42	30	45	—0.98	+0.2	9	7.0	se.	34	sw.	27	6	13	11	5.9	0.0																												
Grand Junction	4,602	60	68	25.30	29.86	—	54.4	+2.0	80	20	66	33	3	43	36	42	30	45	—0.98	+0.2	9	7.0	se.	34	sw.	27	6	13	11	5.9	0.0																												
Northern Plateau																														51.3		+1.5				60		1.38		+0.4																			
Baker <sup>1</sup>	3,373	36	54	26.53	30.02	+0.02	46.0	+0.8	78	13	57	30	2	35	37	40	34	71	—0.85	—0.2	12	6.5	n.	23	n.	15	2	15	13	6.7	1.0																												
Boise <sup>1</sup>	2,858	5	49	27.02	29.98	—	50.0	—	78	13	61	31	10	39	34	43	36	62	1.80	—0.2	12	10.6	nw.	36	nw.	15	4	15	11	6.6	0.0																												
Pocatello <sup>1</sup>	4,478	5	31	25.41	29.93	—	47.4	—	76	13	59	27	12	36	42	40	32	60	1.03	—	9	11.7	sw.	36	w.	20	4	12	14	6.6	T																												
Spokane <sup>1</sup>	1,968	101	110	27.91	30.00	+0.01	50.6	+2.2	74	12	60	34	2	41	35	43	36	1.86	—	+0.7	13	7.4	s.	26	sw.	28	2	11	17	7.3	0.0																												
Walla Walla	991	57	65	28.94	30.02	+0.01	54.8	+1.7	77	17	64	38	3	46	30	46	37	55	1.98	+0.5	10	6.7	s.	23	sw.	9	1	11	18	7.7	0.0																												
Yakima	1,076	58	67	28.86	30.01	—	53.8	+1.3	77	17	64	37	10	43	33	45	33	50	—0.84	+0.4	8	6.7	nw.	24	w.	9	8	7	18	7.1	T																												
North Pacific Coast Region																														53.4		+3.9				74		2.91		—0.1																			
North Head	211	5	59	29.86	30.09	+0.04	52.0	+4.5	73	11	57	44	2	47	24	48	46	83	4.00	—0.0	19	13.6	n.	47	s.	30	1	9	20	7.9	0.0																												
Seattle <sup>1</sup>	14	90	321	30.02	30.05	+0.02																																																					

TABLE 2.—Climatological data for Weather Bureau stations, April 1940—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation			Wind						Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths		Total snowfall	Snow, sleet, and ice on ground at end of month																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. +2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Total				Departure from normal	Days with 0.01 inch or more	Average hourly velocity	Prevailing direction	Maximum velocity			Date																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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<i>Panama Canal</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>N</i>	<i>In.</i>	<i>In.</i>	<i>Miles</i>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										</

1 Data are airport records.

2 Barometric and hygrometric data from airport, other data city office records.

3 Observations taken bi-hourly.

4 Pressure not reduced to a mean of 24 hours.

5 Barometric, hygrometric and temperature records from airport, other data from city office records.

NOTE.—Except as indicated by notes, 1 and 2, data in table 2 are city office records.

TABLE 3.—Data furnished by the Canadian Meteorological Service, April 1940

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. +2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
		In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	In.	In.	In.
Cape Race, Newfoundland.....	99				33.8	+1.0	38.7	28.9	48	19	5.15	+1.06	T
North Sydney, Cape Breton Island.....	48	29.90	29.91	-0.01	34.6	-.9	41.4	27.8	56	16	3.94	+0.07	11.9
Halifax, Nova Scotia.....	88	29.66	29.93	.00	37.0	-2.4	43.5	30.4	60	20	5.72	+1.17	7.2
Yarmouth, Nova Scotia.....	65	29.82	29.93	-.02	38.0	-1.9	45.4	30.7	60	25	4.81	+1.12	1.9
Charlottetown, Prince Edward Island.....	38	29.86	29.95	+0.03	35.8	-.8	42.6	29.1	62	19	3.18	-.49	17.5
Chatham, New Brunswick.....	28	29.81	29.92	-.02	34.8	-3.3	43.1	26.6	70	10	2.28	-.73	10.3
Father Point, Quebec.....	20												
Quebec, Quebec.....	296	29.61	29.95	-.01	36.2	-.2	42.8	29.7	68	15	4.30	+1.88	22.8
St. Hubert Airport 1.....	102	29.84	29.95	-.01	38.2	-2.8	45.7	30.6	74	19	2.47	-.9.6	3.6
Ottawa, Ontario.....	236	29.57	29.95	-.03	37.0	-4.5	45.0	29.0	74	16	3.15	-.87	4.4
Kingston, Ontario.....	285	29.66	29.98	-.01	38.6	-2.6	46.3	30.8	69	17	3.79	+1.46	1.8
Toronto, Ontario.....	379	29.57	29.99	-.02	41.4	-1.4	49.0	33.7	67	19	2.53	-.12	4.1
Porquois Junction.....					29.2		39.7	18.7	73	0	.65		3.1
White River, Ontario.....	1,244	28.69	30.07	+0.05	30.0	-2.0	43.3	16.6	58	-7	2.12	+.58	7.6
London, Ontario.....	808	29.10	30.00		39.9	-3.9	49.3	30.5	73	17	2.87	+.05	5.4
Southampton, Ontario.....	656	29.28	30.00	+0.01	37.0	-3.0	44.9	29.1	77	19	1.70	-.59	3.0
Parry Sound, Ontario.....	688	29.29	29.99	.00	37.6	-1.6	47.1	28.0	77	15	2.09	-.19	4.2
Port Arthur, Ontario.....	644	29.36	30.08	+0.05	34.0	-1.5	43.6	24.3	59	7	1.71	+.27	3.5
Winnipeg, Manitoba.....	760	29.22	30.11	+0.03	36.2	-1.8	46.5	25.8	69	6	1.65	-.31	3.5
Minneapolis, Manitoba.....	1,690	28.27	30.13	+0.12	36.2	-1.4	46.5	25.8	70	5	.01	-1.15	T
Le Pas, Manitoba.....	860	29.18	30.17	+0.14	34.0	+1.0	47.0	21.1	72	-6	.63	-.07	1.7
Qu'Appelle, Saskatchewan.....	2,115	27.79	30.12	+0.12	34.6	-2.8	43.9	25.2	65	3	1.14	-.01	11.4
Regina, Saskatchewan.....	1,900	28.07	30.13		35.4	-2.4	44.0	26.7	64	-1	.72	-.02	7.1
Swift Current, Saskatchewan.....	2,392	27.25	30.14	+0.17	33.4	-7.9	41.1	25.6	63	-9	1.37	+.55	10.9
Medicine Hat, Alberta.....	2,365	27.54	30.08	+0.14	38.1	-6.9	46.8	29.4	73	-8	2.45	+1.70	11.4
Calgary, Alberta.....	3,540	26.36	30.12	+0.17	34.4	-5.5	41.8	27.1	67	-7	3.54	+2.59	21.0
Banff, Alberta.....	4,521												
Prince Albert, Saskatchewan.....	1,450	28.58	30.16	+0.16	36.0	-.6	47.4	24.7	66	-2	.04	-.88	T
Battleford, Saskatchewan.....	1,692				35.2	-3.0	45.7	24.6	67	-6	.14	-.48	.8
Edmonton, Alberta.....	2,150	27.70	30.11		34.0	-5.6	41.6	26.4	62	-8	2.62	+1.71	9.8
Kamloops, British Columbia.....	1,262	28.64	29.97	+0.01	51.1	+1.5	63.1	39.1	72	33	.61	+.20	.0
Victoria, British Columbia.....	230	29.79	30.04	+0.01	51.7	+3.3	58.2	45.2	70	39	1.39	-.05	.0
Barkerville, British Columbia.....	4,180												
Estevan Point, British Columbia.....	20												
Prince Rupert, British Columbia.....	170	29.79	29.98	+0.04	47.3	+4.0	55.0	39.0	69	32	9.65	+2.70	.0
St. George's, Bermuda.....	151												
<b>LATE REPORTS FOR MARCH 1940</b>													
Prince Rupert, British Columbia.....	170												
St. George's, Bermuda.....	151	29.99	-.09	61.4	-1.4	66.3	56.6	74	49	3.45	-1.16	.0	

1 Pressure not reduced to a mean of 24 hours.

2 Observations taken at St. Hubert Airport of Montreal.

TABLE 4.—Severe local storms, April 1940

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as has been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Wheaton, Ill.	2				\$1,000	Electrical	Barn destroyed.
Day County, S. Dak.	2				4,000	Wind and rain	Small buildings blown down; roadbeds and grades washed out.
Kenton, Okla.	2-3	Midnight of 2d-2 a. m. of 3d.	120		500	Wind	Property damaged; telephone lines down; path 50 miles long.
Duluth, Minn., and vicinity	2-5				358,000	Gleaze	This storm extended from Iron River, Wis., to the west, near Atkin, Minn., to the north, near Grand Rapids, Minn., and, to the east, to Beaver Bay, Minn. The heaviest ice formed in the St. Louis River Valley from Duluth to beyond Carlton, Minn. Loss to overhead wire systems, trees, and other property.
Cordova, Ala.	3	6:30-7 p. m.			75,000	Hail	Property damaged.
Mattoon, Ill.	3				6,500	Wind	Do.
Mayna, La.	6	8:45 p. m.	1,320	0	6,000	Tornado	Property damaged; 2 homes destroyed; trees uprooted.
Amite, La.	7	12:07 a. m.	100	3	500,000	do	25 persons injured; 50 homes demolished and much damage occurring in 6 business blocks.
Ponchatoula, La., vicinity of	7	12:30 a. m.	440	0	8,250	do	Property damaged; 5 persons injured.
Mandeville, La.	7	1:00 a. m.			6,000	Wind	Property damaged.
Lafitte and Barataria, La., vicinity of	7	2:15 a. m.	440	2	5,000	Tornado	Do.
Vacherie, La.	7	6:15 a. m.	25	0	3,000	do	Property damaged; 1 person seriously injured.
Troy, Ala.	7	1 p. m.			5,000	do	Do.
Hillsboro, Tex., vicinity of	7		1-2	1		Rain	Man drowned when he lost his balance and was washed out of sight while attempting to wade across Highway 22, near the Hillsboro city limits; path 15 miles long.
Tyler, Tex.	7				87,500	Hail	Loss in crops, orchards and roses; property damaged.
Woodward, Okla.		Midnight	12		500	Hail	Property damaged; path 15 miles long.
Cheyenne, Okla.	10	8:30 p. m.	121		35,000	do	Loss to grain; property damaged; path 40 miles long.
Cordell, Okla.	10	do	110		6,000	do	Loss to crops, \$5,000; property damage, \$1,000; path 10 miles long.
Watonga, Okla.	10	8:30-9:10 p. m.	12		1,450	Hail and wind	Loss in wheat, oats, and barley, path 3 miles long.
Geary, Okla., 5 miles northwest	10	8:45 p. m.	14		3,500	Hail	Property damaged; path 8 miles long.
Clinton and Arapaho, Okla.	10	9:30-10:30 p. m.	15		260,000	Hail and wind	Loss in small grains, fruits, gardens, and shrubs; path 10 miles long.
Altus, Okla.	10	10:40 p. m.	880		2,000	Wind	Property damaged; 2 persons injured; path 6 miles long.
Wilson County, Kans.	16	6:30-7:15 p. m.	112		5,000	Heavy hail and wind	Storm extended from New Albany to Benedict and southward across the greater part of the county; path 20 miles long.
Burdett to Larned, Kans., and vicinities	16	8-8:45 p. m.			40,000	Wind	Property damaged; path several miles wide and 30 miles long.
Raymond and Geneseo and Frederick, Kans.	16	9:30-10:10 p. m.	880		10,000	Tornadoic wind	Storm extended from the oil fields in the vicinity of Raymond to the vicinity of Geneseo. Residences in Frederick and farm buildings and telephone lines blown down; path 22 miles long.
Chanute, Kans., vicinity of	16	9:45 p. m.			1,000	Wind	2 garages, 1 southwest, the other northeast of Chanute demolished; path narrow and short.
Sedgwick County, Kans.	16-17	Midnight	12		10,000	Heavy hail	Chief damage occurred over a strip from Haysville to the county line; path 12 miles long.
Houma, La., 6 miles southeast	17	6:30 a. m.	50	1	2,500	Tornado	Property damaged.
Raceland, La.	17	7:15 a. m.	130		3,000	Wind	Do.
Vanderburg County, Ind.	17	10 a. m.			900	Wind and hail	Property damage including that of an airplane.
Elizabeth Odum, and Bethel, La., and vicinities	17	6:55 p. m.	440		35,000	Wind	Property damaged.
Windsor, Ill.	17				500	Hail	Do.
Mount Holly, N. C., eastern edge	19	5:40 p. m.		0		Small tornado and heavy rain	Cotton gin and several buildings demolished; 1 person injured; path a few yards wide and about 100 yards long.
Campbell County, Va.	20	2-3:30 p. m.	12		17,500	Hail	Loss to crops, \$6,000; property damage, \$11,500; path 25 miles long.
Chinook, Mont., vicinity of	20				2,700	Rain and flood	Creeks flooded; farmlands inundated; property damaged; 10 families forced to abandon homes.
Paris, Tex.	22	5:30 p. m.	2,640		550,000	Hail	Property damage, \$550,000; crop loss considerable, but not estimated.
Gooding, Idaho	26	4 p. m.	200	0	25,000	Tornado	Buildings on 5 farms demolished; small crop loss not estimated; livestock and poultry killed; path about 2 miles long.
Imperial, Nebr.	27	2:30 p. m.	100	0	2,000	do	Buildings on 3 farms damaged; 4 cattle killed.
Harrison, Nebr.	27	4:30 p. m.	11		500	Hail	Property damaged.
Ogallala, Nebr., 8 miles north	27	4:45 p. m.	183	0	5,000	Tornado and hail	A cement plant wrecked; 1 person slightly injured.
Arnold, Nebr.	27	6:45 p. m.	880	0	40,000	do	Five residences demolished; others damaged; 1 person injured.
Brown, Redwood, Renville, Kandiyohi, and Meeker Counties, Minn.	27-28	9 p. m.-3 a. m.	125		25,000	Thundersqualls	Several barns, outbuildings, and silos wrecked; many town and farmhouses and barns damaged; poles and wires down; trees broken.
Lenora, Kans., 4 miles south	28	6 p. m.	440	0	2,000	Small tornado	Damage to farm property; path west-southwest and 3 miles long.
Quinter, Kans., vicinity of	28	6:30 p. m.		0		do	Storm moved southwest over a narrow path 4 miles long. No buildings of consequence in path, only little damage occurring.
Horton, Kans., 12 miles southeast	28	7 p. m.		0	2,000	Tornado	Damage to farm property. Several small vortex clouds in addition to the main storm. Path narrow, from the southwest and 6 miles long.
Horton, Kans., vicinity of	28	7-9 p. m.	440		2,000	Heavy hail and wind	Hail drifted to depth of 4 to 5 inches and was accompanied by severe wind-squalls. Path from the south and 4 miles long.
San Jose, Delavan and Hopedale to Pontiac, Ill.	29	3-4:45 p. m.	50-74	1	85,000	Tornado	This storm began south of San Jose about 3 p. m., moving into adjoining Logan County, passing 3½ miles south of Delavan and over Hopedale at 3:30 p. m. The distance traveled to this point was about 14 miles affecting a path approximately 50 to 75 yards wide. Near Hopedale some farm buildings were lifted from their foundations. The storm apparently lifted after passing Hopedale, but dipped again 30 miles northeastward about 4:45 p. m., at a point a few miles southwest of Pontiac and continued for about 10 miles. In this area 1 person was killed and 20 injured. Most of the damage in Pontiac was in the northwestern section. Property damage amounted to approximately \$25,000 along a path 83 yards long. A tank weighing a ton carried 40 feet.
Bell City to Hayes, La.	29	3:30 p. m.			16,000	Rain and wind	Property damage, \$10,000; crop loss, \$6,000.
Alva, Okla.	29	4:40-4:54 p. m.	13			Hail	Loss in early wheat crop; corn and gardens almost a total loss. Damage considerable, not estimated.
Rapides, Avoyelles, Pointe Coupee, and West Feliciana Parishes, La.	29	11 p. m.-midnight			170,000	Wind and hail	Much crop loss from hail; 17 persons injured; property damage, \$100,000.
Delavan, Ill.	29				10,000	Heavy hail	Property damaged.
Hopedale, Ill.	29				4,500	do	Do.
Slidell, Tex.	29	4:30 a. m.	2,640	0	1,250	Tornado	Loss to crops, \$250; property damage, \$1,000.
Illinois	30		100-650	1	210,000	2 tornadoes	Each tornado listed separately below. \$210,000 damage from 2 tornadoes.
Cache to America, Ill., vicinity of	30	5 p. m.	100-650	0		Tornado and hail	Greatest damage from North Mounds to America. 3 funnel clouds observed.

See footnotes at end of table.

TABLE 4.—Severe local storms, April 1940—Continued

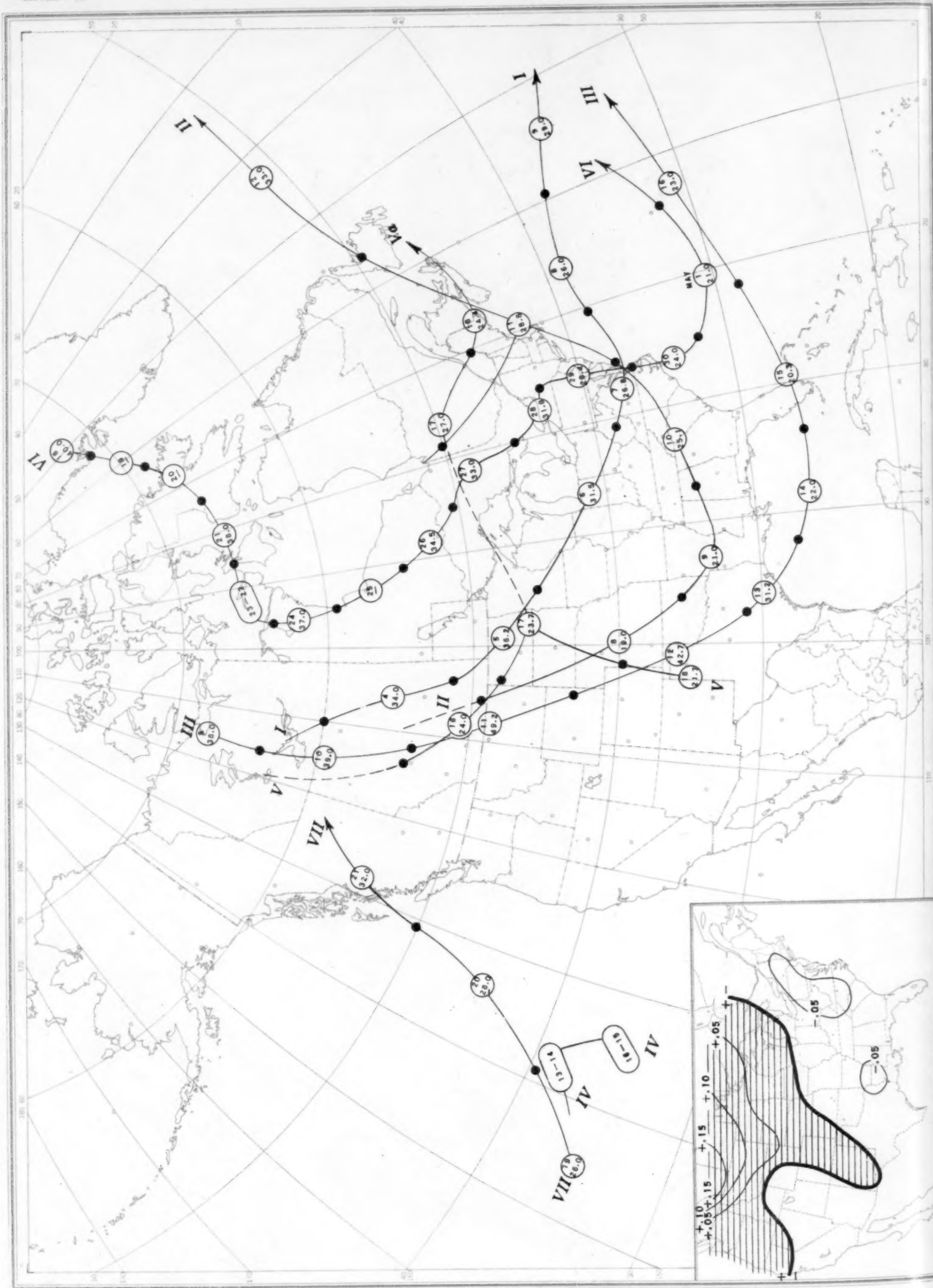
Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Olive Branch, Sandusky, Pu-laski, Ullin, Grand Chain, Belknap and Golconda, Ill., and vicinities.	30	6 p. m.	325	1		Tornado and hail.	More than 13 persons sent to hospitals, many more receiving medical attention. Large number of homes, barns and outbuildings, several churches and schools destroyed.
Richland to Carthage, Tex.	30	5:40-7:15 p. m.		3	\$112,500	Tornado.	Property loss in the two storms, \$200,000; crop loss, \$10,000. Loss to crops, \$10,000; property damage, \$102,500; width of path, 20 yards to 5 miles.
Longview, Tex.	30	5:45 p. m.	17		125,000	Wind	Property damaged; 2 persons injured.
Tull to Ico, Ark., and vicinity.	30	6 p. m.	440	6	8,800	Tornado	4 houses destroyed and other property damaged. 9 persons injured. Crop loss, \$800; property damage, \$8,000; path 15 miles long.
Centerville, Tex.	30	7:30 p. m.	115		18,000	Hail	Loss to crops, \$8,000; property damage, \$10,000.
Vanderburg County, Ind.	30	9:30 p. m.			50,000	Wind	Wind velocity of 56 miles per hour recorded; wires and trees down; buildings damaged.
Thomasville, Ala.	30	P. m.			2,500	Cloudburst	Main portion of town flooded water reaching the depth of 6 inches in some of the stores.
Reevesville, Ill.	30				3,000	Wind	Property damaged.
Rosiclare, Ill.	30				3,000	do.	Do.

<sup>1</sup> Miles instead of yards.<sup>2</sup> From press reports.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, and Wind Roses for Selected Stations, April 1940



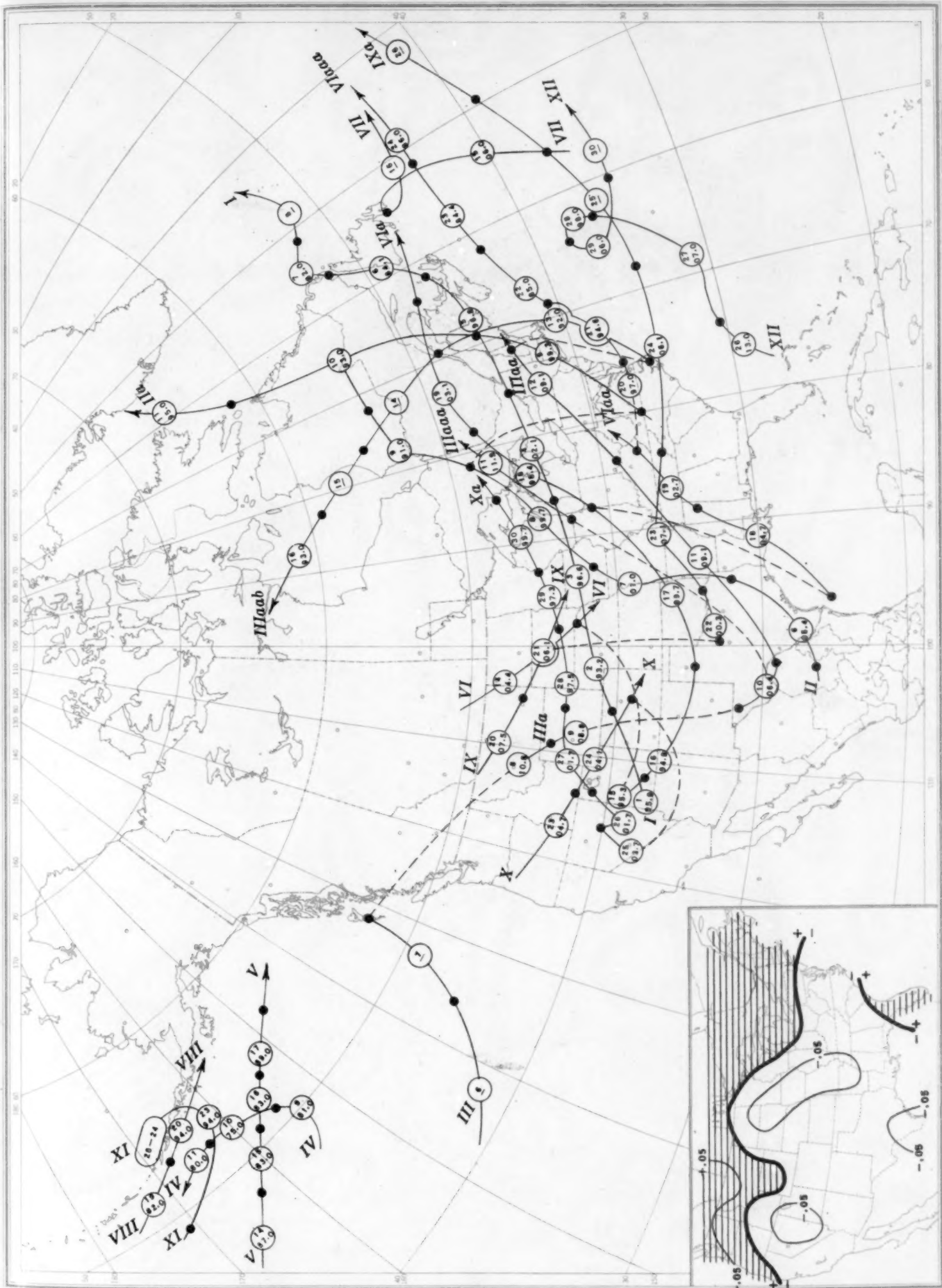
Chart II. Tracks of Centers of Anticyclones, April 1940. (Inset) Departure of Monthly Mean Pressure from Normal



Circle indicates position of anticyclone at 7:30 a. m. (76th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (76th meridian time).

Chart III. Tracks of Centers of Cyclones, April 1940. (Inset) Change in Mean Pressure from Preceding Month

Chart III. Tracks of Centers of Cyclones, April 1940. (Inset) Change in Mean Pressure from Preceding Month



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, April 1940

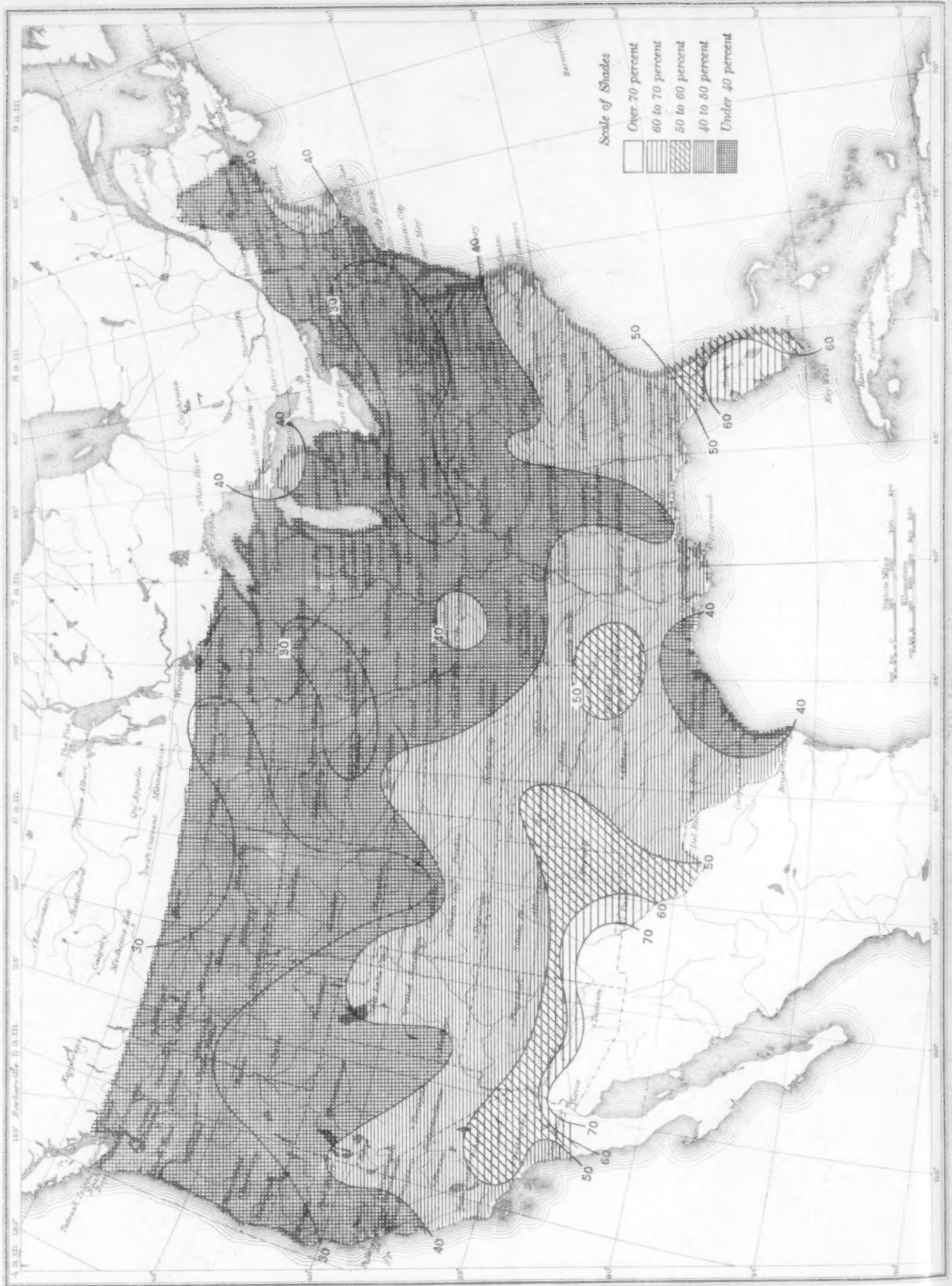


Chart V. Total Precipitation, Inches, April 1940. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, April 1940. (Inset) Departure of Precipitation from Normal

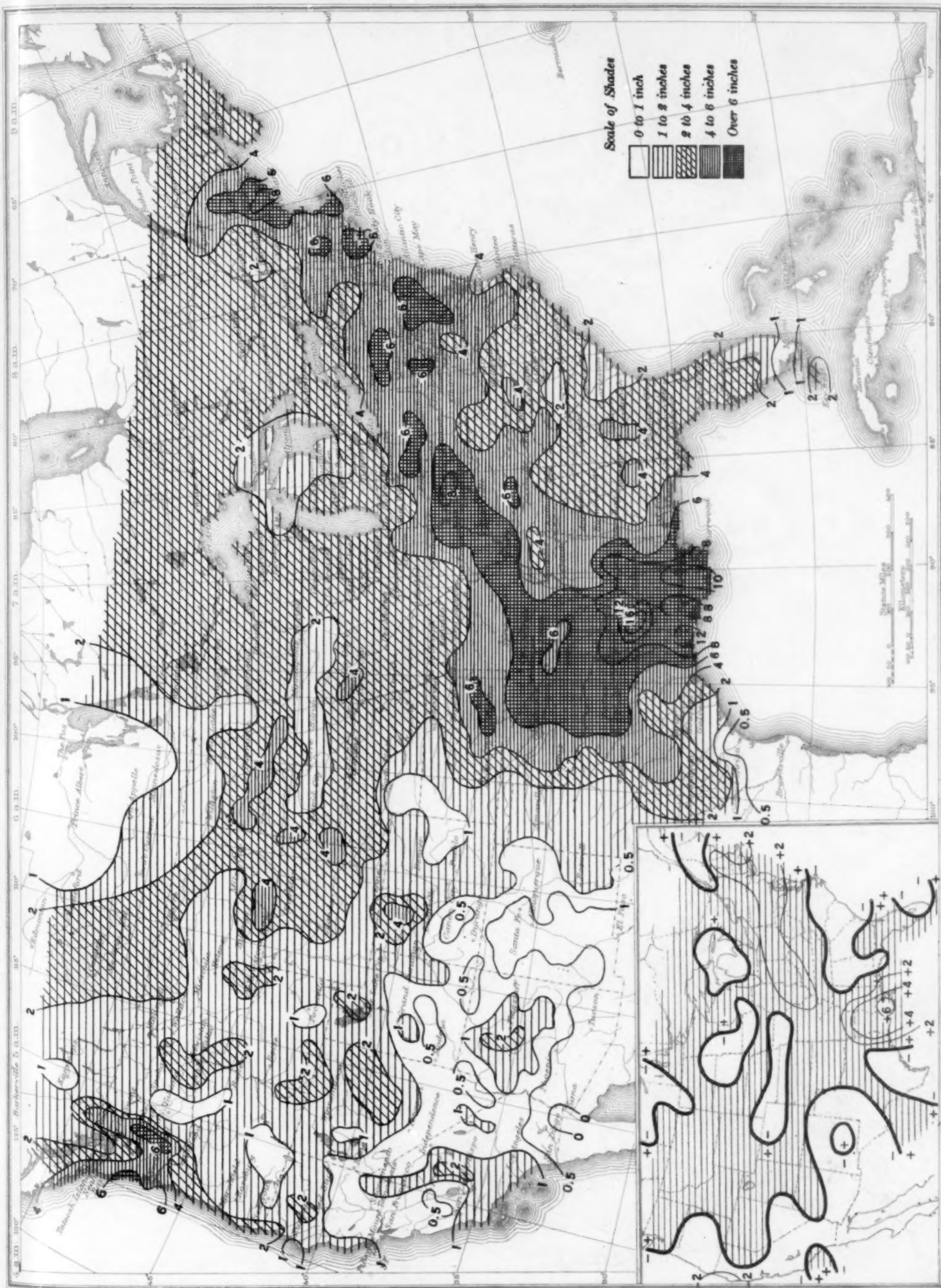


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, April 1940

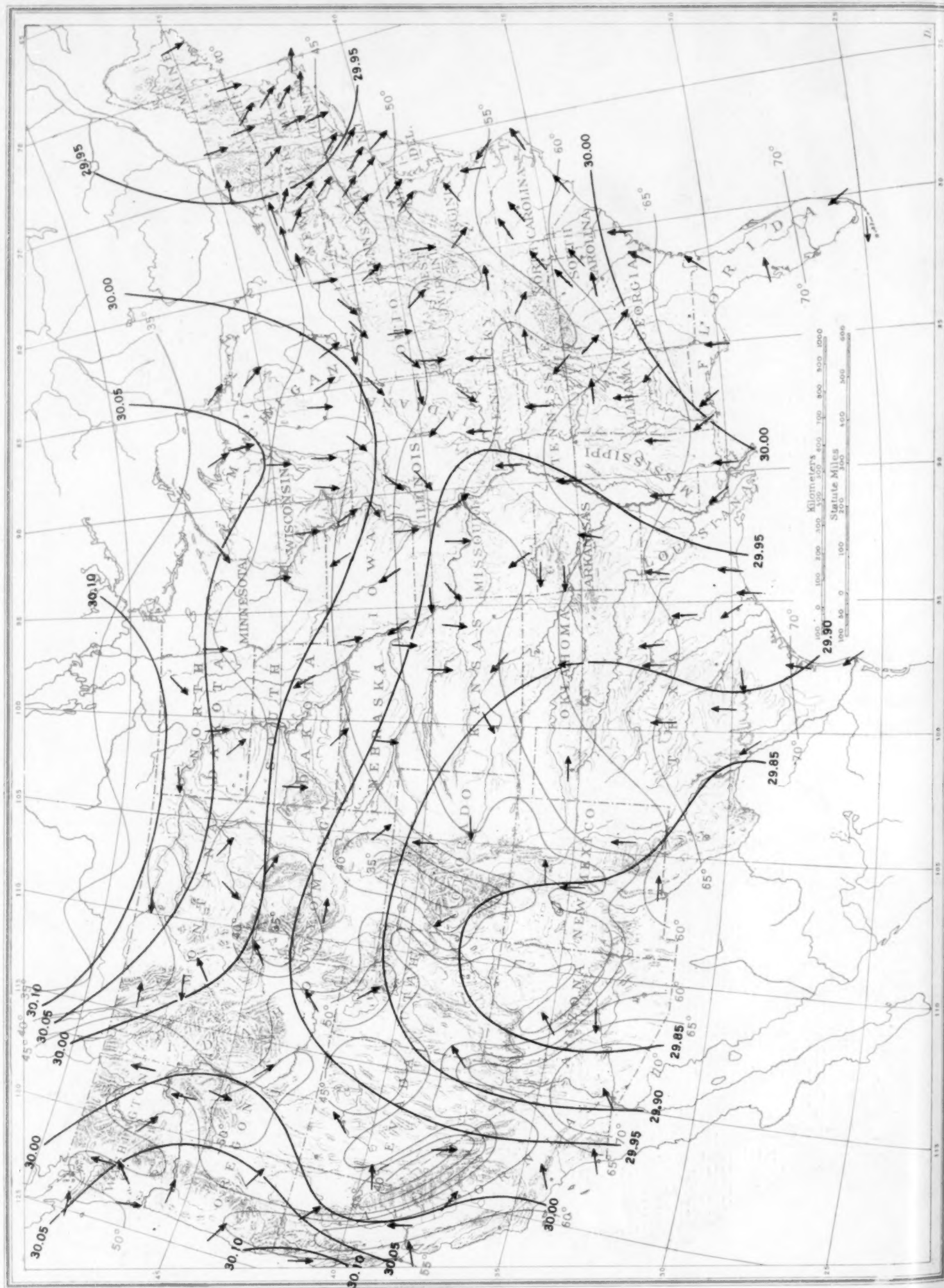


Chart VII. Total Snowfall, Inches, April 1940.

Chart VII. Total Snowfall, Inches, April 1940.

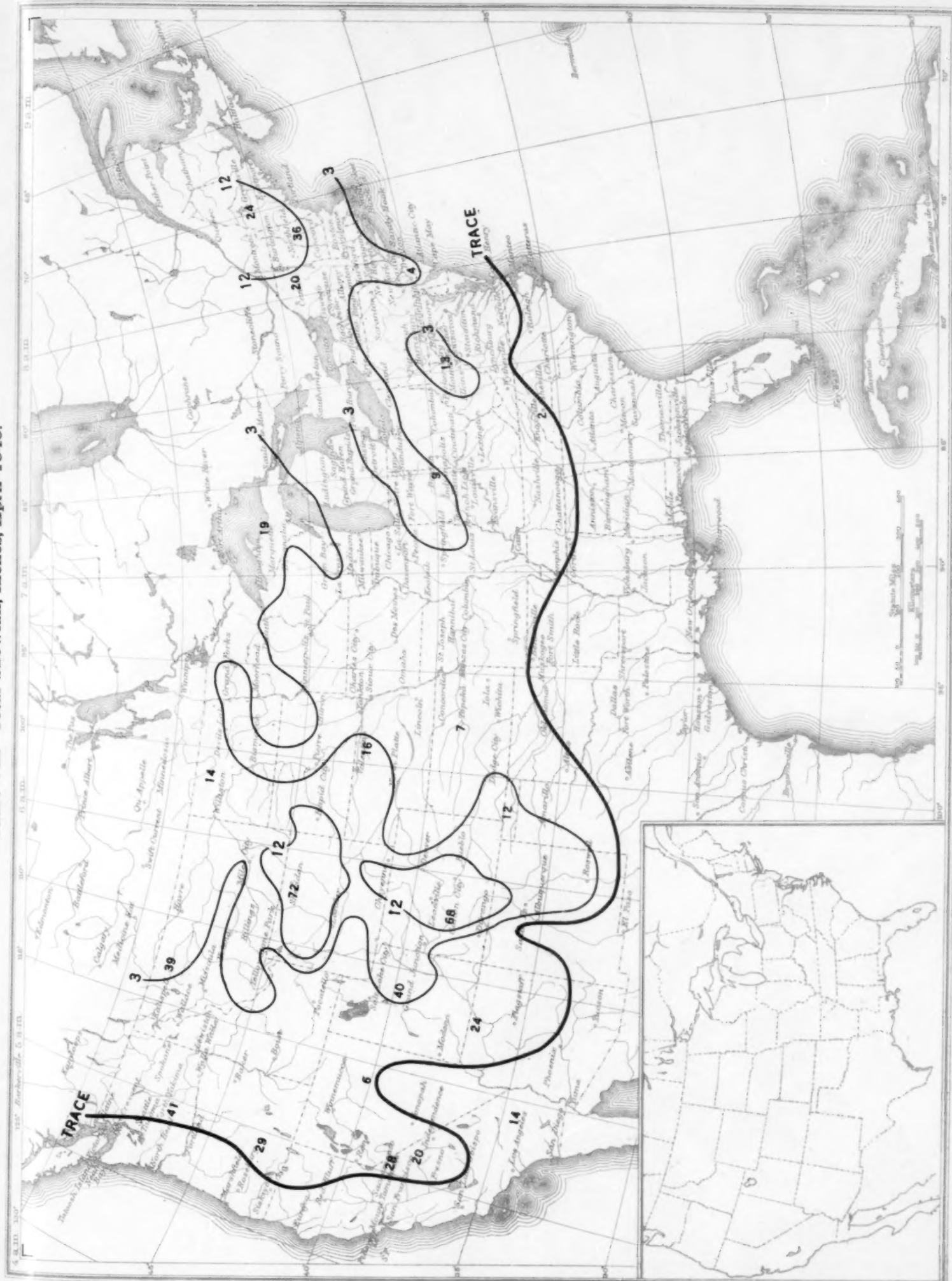




Chart VIII. Isobars (mb) for 1,524 Meters (5,000 ft.) and Isotherms (°C.) and Resultant Winds for 1,500 Meters (m. s. l.) April 1940

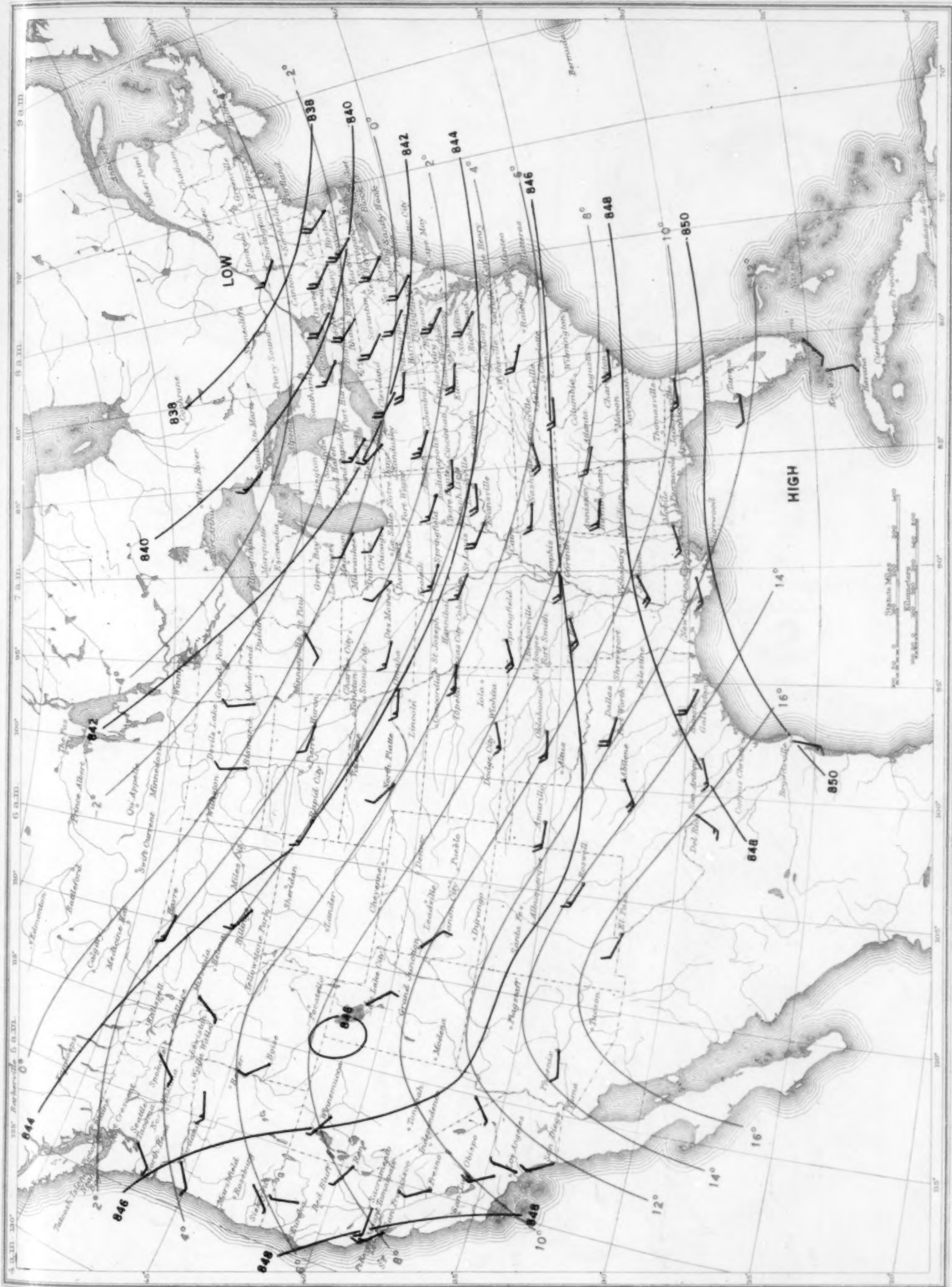


Chart IX. Isobars (mb) Isotherms (°C.) and Resultant Winds for 3,000 Meters (m.s.l.) April 1940

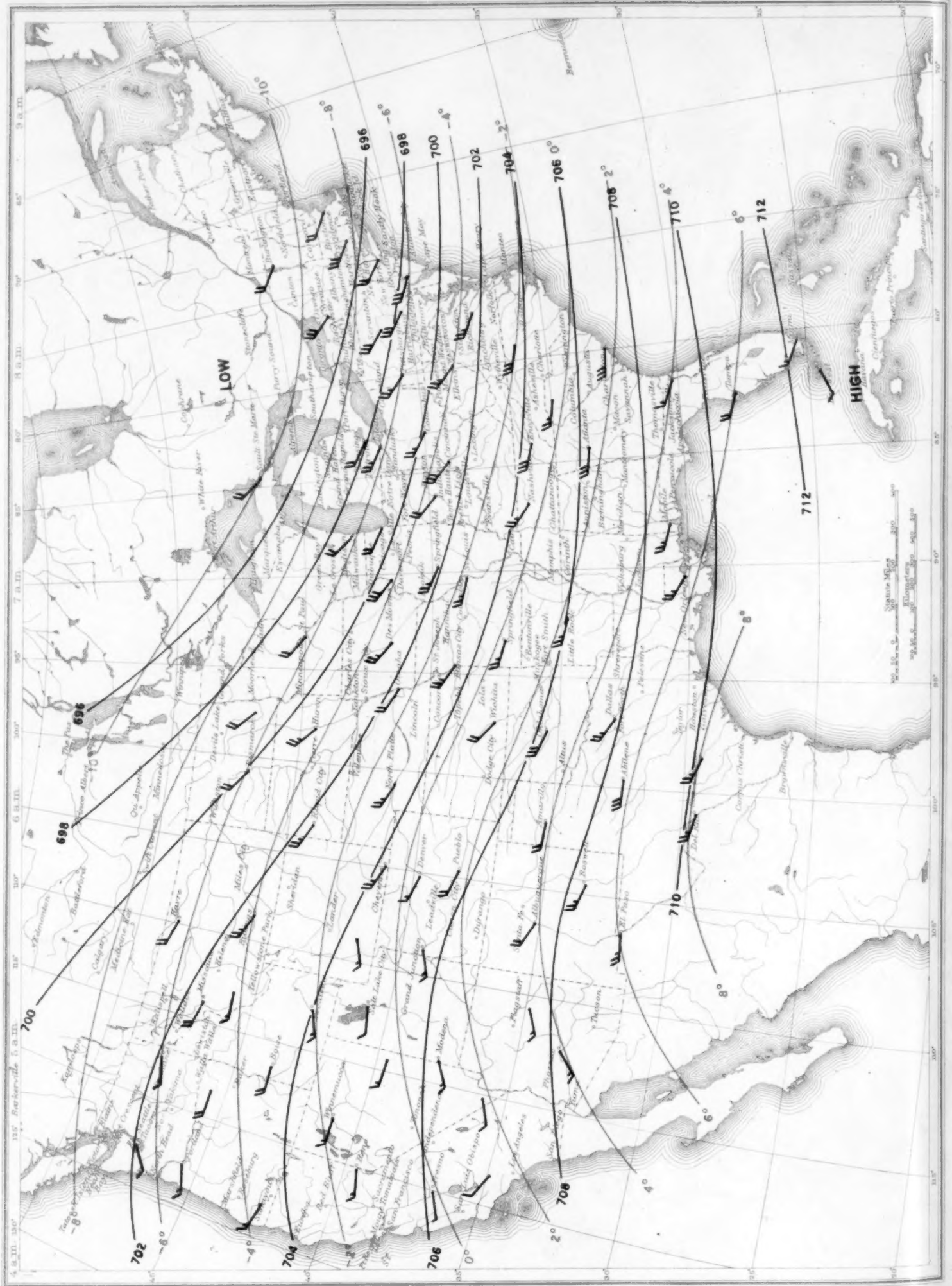


Chart X. Isobars (mb) Isotherms (°C.) and Resultant Winds for 5,000 Meters (m.s.l.) April 1940

Chart X. Isotherms (mb) Isotherms ( $^{\circ}\text{C}$ .) and Resultant Winds for 5,000 Meters (m. s. l.) April 1940

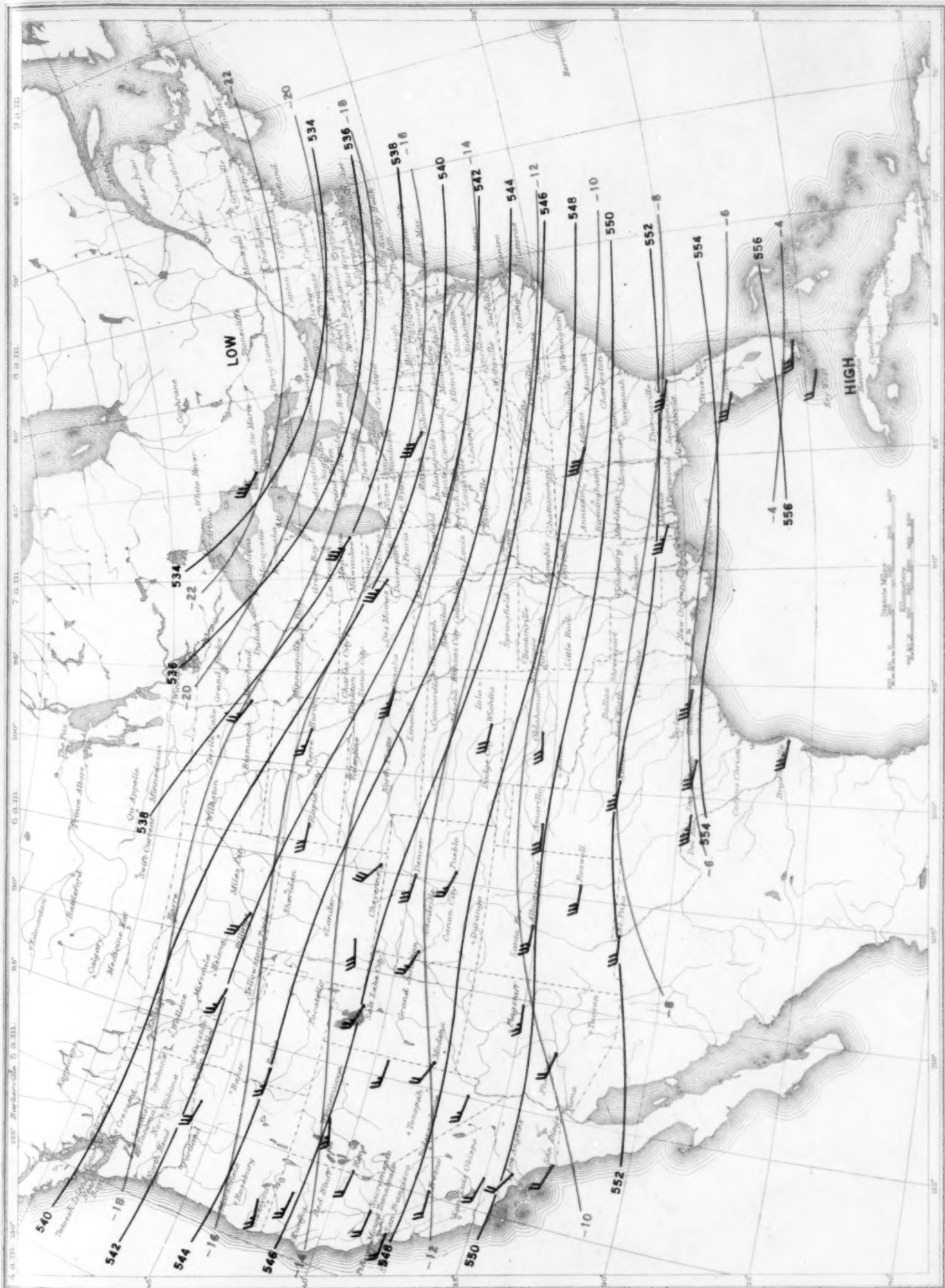


Chart XI. Isobars (mb) Isotherms (°C.) and Resultant Winds for 10,000 Meters (m.s.l.) April 1940

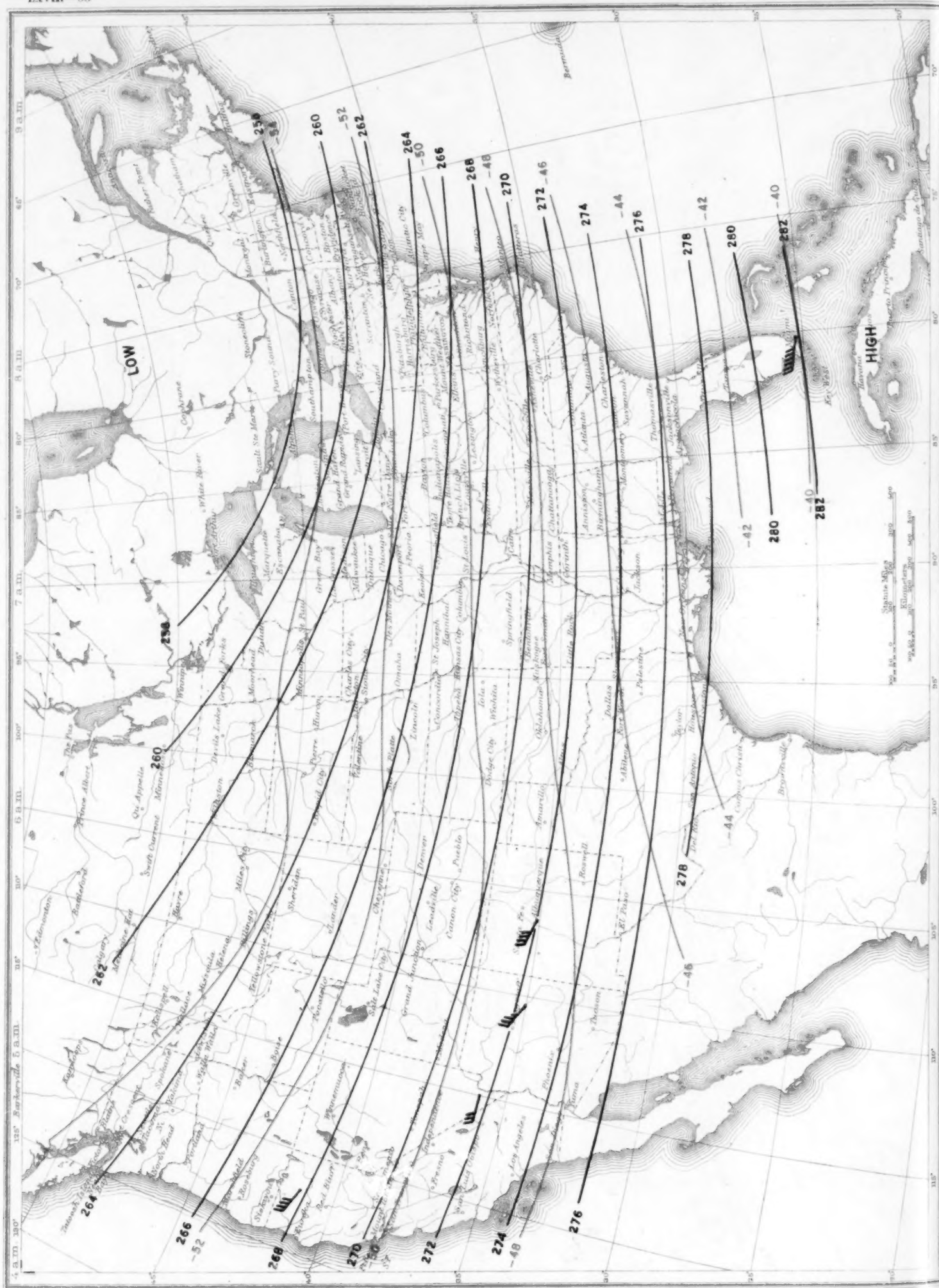


Chart XII. Mean Isentropic Chart, April 1940 (Potential Temperature 304° A.)

Chart XII. Mean Isentropic Chart, April 1940 (Potential Temperature 304° A.)

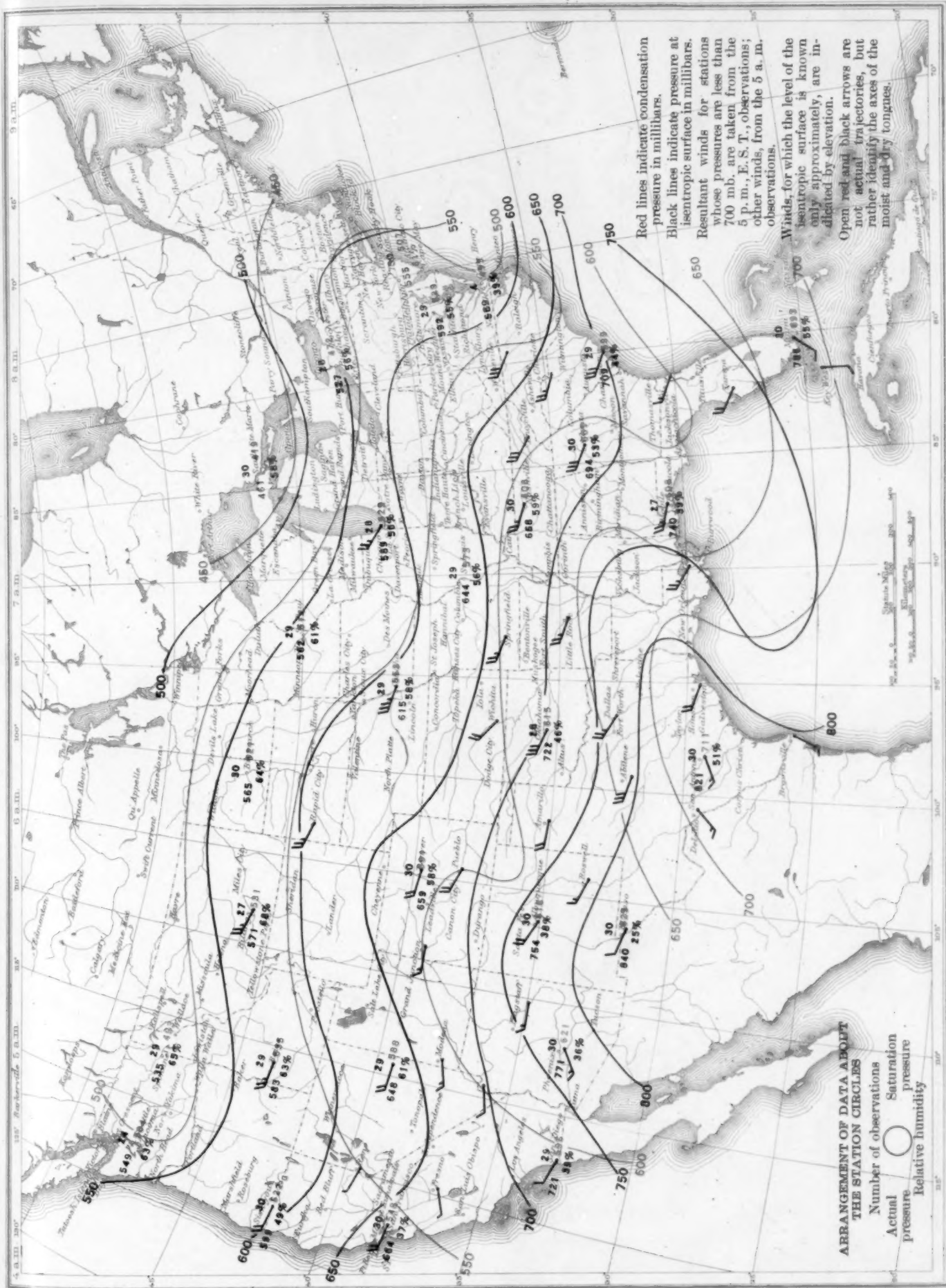


Chart XIII. Mean Tropopause Data, Altitude (km.) (m. s. l.) Temperature (°C.) April 1940  
(Data from table 4)

